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Railyard Noise Exposure Model (RYNEM)
Volume 1. Description of RYNEM Model

Energy Resources Co., Inc.
Vienna, VA

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Washington, DC

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RAILYARD NOISE EXPOSURE MODEL (RYNEM)

Volume 1

Description of RYNEM Model

January 1982

U.S. Environmental Protection Agency
Washington, D.C. 20460

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Volume 1

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U.S. Environmental Protection Agency
Washington, D.C. 20460

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This volume presents an overview of the RYNEM model. The basic philosophy of the model is discussed and the relevant equations used in the computations are presented. This volume is written for those who need to know what the model is like. It does not go into detail of how each computation is done in the program, nor does it teach the user how to run the model. It presupposes some familiarity with the EPA noise terminology, as is covered by the "EPA Levels" document. The reader is advised to peruse the Railroad Background document for other terminology used without explanation.

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Railyard Noise Exposure Model
Volume 1. Description of Model

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0.0 PRELIMINARIES

0.1 Scope of These Manuals

The present set of manuals, volumes 1-3, is meant to describe the Railyard Noise Exposure Model (RYNEM) in some detail. In the following, a brief description of each volume and its intended audience is presented.

Volume 1: General Description of the Model

This volume presents an overview of the model. The basic philosophy of the model is discussed and the relevant equations used in the computations are presented. This volume is written for those who need to know what the model is like. It does not go into detail of how each computation is done in the program, nor does it teach the user how to run the model. It presupposes some familiarity with the EPA noise terminology, as is covered by the "EPA Levels" document [1]. The reader is advised to peruse the Railroad Background document [2] for other terminology used without explanation.

Volume 2: User Manual

This volume presents a cookbook approach to the execution of the model. Its intended audience is those who will exercise the model. It assumes familiarity with volume 1, i.e., the user knows the quantities he inputs, and he knows the quantities printed out. For obvious reasons, the explanations incorporated in volume 1 are not repeated. While it does not presume expertise with the EPA IBM computer system, it does assume the user can follow the instructions presented in this volume to the letter. This point cannot be emphasized often enough. Contrary to popular opinion, a computer cannot think. It can only carry out the instructions given it exactly. As far as is known, the present program is bug-free. If an error occurs, the source most likely is in the input data or the job card.) Though the manual presents a short description of relevant commands in the appendix, the user is reminded that EPA changes its computer systems every so often, so that the instructions presented may be obsolete. The user is strongly advised to obtain a copy of the latest computer user guide and learn the necessary commands to make runs.

Volume 3: Programmer Manual

This volume describes all the nuts and bolts in the program code. It is not meant to teach the reader how to run the program. That is the job of volume 2. It assumes the reader has digested the contents of volume 1. No attempt has been provided to educate the reader as to what Ldn or LWP is. The intended audience is the programmer who needs to maintain the program and make changes in the code. A strong knowledge of standard IBM FORTRAN IV language is assumed.

The correct sequence of reading for a rank novice with no knowledge whatsoever of the EPA noise model methodology is as follows:

1. EPA Levels document - in which the terminology is introduced.
2. Railroad Background document - which describes what a railyard is, the noise sources inside, etc.

3. Volume 1 - what the model attempts to do.
4. Volume 2 - how to make the program grind out numbers.
5. Volume 3 - how the code achieves the aims of volume 1.

Volumes 2 and 3 are not necessary for the person who only wants to understand what RYNEM is about. Volume 2 is not necessary for the person who only wants to exercise the model. For the programmer who maintains the code and to whom job failures will be reported, an intimate knowledge of all three volumes is necessary.

References

[1] Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety, 550/9-74-004, U.S. EPA, Washington, D.C., March 1974.

[2] Background Document for Proposed Revision to Rail Carrier Noise Emissions Regulation, 550/9-78-207, U.S. EPA, Washington, D.C., February 1979.

0.2 General Introduction to the Model

The Railyard Noise Exposure Model (RYNEM) is a computer program designed to quantify the health/welfare impact due to railyard-generated noise on the general population. In this model, a railyard contains two causes of noise sources: stationary and moving. Some examples of stationary sources are master retarders (MR), inert retarders (IR), crane trucks (CT), goat trucks (GT), idling locomotives (IL), refrigerator cars (RC) and load tests (LT). Moving sources consist of switch engines (SE) and inbound (IB) and outbound (OB) trains. Each of these noise sources generates a noise level which can be measured at the railyard boundary (property line). Together, they combine to produce a higher noise level than each can produce on its own. Taking into account the hours of the day during which the noise sources are used, an averaged noise level, Ldn (for day-night weighting) can be computed at the railyard property line using the standard EPA methodology. Based on this Ldn value the general adverse response level weighted population (LWP), or equivalent number impacted (ENI) can be computed.

So far, this is standard practice of the EPA noise models. Whereas formerly, the EPA noise models would use some kind of "average" parameters to construct a model of an "average" yard and then scale up the LWP from this "average" yard to the total population of yards for the national impact, RYNEM does the scaling in a slightly different way. RYNEM considers that the LWP for the national population of railyards form a distribution with mean μ and variance σ^2. When random samples are taken from this distribution and their mean, $\hat{\mu}$, computed, the Weak Law of Large Numbers implies that the sample mean approaches the true mean of the population when the sample size is large, i.e., the sample mean μ is a good approximation of the true

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mean μ. If we scale up the sample mean LWP by the total number of yards in the population, we will obtain a good approximation to the total LWP due to all the yards, when our sample size is large enough. In this sense, RYNEM is a "statistical" model.

An estimate of the error involved in $\hat{\mu}$ can be obtained as follows:

The true variance of the population, σ^2, can be approximated by the sample variance:

$$S^2 = \sum_{i=1}^{n} \frac{(xi - \hat{\mu})^2}{n-1}$$

where xi are the individual LWP's
n is the sample size.

Let $xi \overset{iid}{\sim} f(\mu,\sigma^2) \quad i = 1, \ldots, n$
Then for

$$Z = \frac{Xit \ldots tXn}{n}$$

$$E(Z) = \mu$$

$$\mathrm{var}(Z) = \frac{\mathrm{var}(xi)}{n} = \frac{\sigma^2}{n}$$

Thus, the standard error of Z is $\frac{\sigma}{\sqrt{n}}$ or approximately $\frac{S}{\sqrt{n}}$.

Therefore, the error of the total LWP is approximately $\frac{SN}{\sqrt{n}}$ where N is the total number of railyards in the population.

DESCRIPTION OF THE MODEL

1.0 General Description

1.1 Introduction

Section 17 of the Noise Control Act of 1972 directed the U.S. EPA to establish noise control limits for the facilities and equipment of interstate rail carriers. Final noise regulations were promulgated in 1975 for moving locomotives and railcars (rolling stock). Subsequent court rulings ordered the EPA to additionally promulgate comprehensive noise standards for the remaining railroad equipment and facilities. In general, in addition to rolling stock operations, the major noise producing activities are associated with equipment and facilities operating within the boundaries of railyards.

In response to these directives, the Office of Noise Abatement and Control (ONAC) of the EPA has conducted studies to categorize the railyard facilities and identify the types of noise sources operating therein. Also, ONAC has conducted a series of health and welfare impact assessments which were essential in providing a quantitative basis for comparing on a national scale the relative benefits and costs of various regulatory alternatives. The magnitude of railyard noise impact was measured in terms of population exposed (PE), or the number of people subjected to noise levels greater than the criterion level (the noise exposure limit requisite to protect the public health and welfare), and in terms of the Equivalent Number of People Impacted (ENI), or the Level Weighted Population (LWP), which is an integration of the number of people exposed above the criterion and the degree of exposure for people subjected to each noise level range above the criterion (1, 2, 17, 20). The noise exposure rating scale used is the average day-night noise level (Ldn) which was developed by the EPA for measuring community annoyance or general adverse response, and which is based on the A-weighted sound level measurement scale.(3) The noise criterion or limit determined by the EPA as requisite to protect the public health and welfare is Ldn = 55dB.(3) The costs associated with the noise control regulation of railyard facilities were determined in terms of available and feasible procedures and technologies (i.e., mufflers, noise enclosures or barriers) for specific items or types of equipment and for the railyard in general (i.e., noise barrier walls constructed along the yard boundary, purchase of land to create buffer zones).

Therefore, a noise generation and propagation computer model called the Railyard Noise Exposure Model (RYNEM), was developed to conduct the health and welfare impact and cost assessment. The purpose of this document (Volume 1) is to describe the computer model, the input data required, and results generated. The use and programming of the model are discussed in detail in the companion documents - Volume 2 RYNEM User Manual, and Volume 3 RYNEM Programming Manual.

The railyard noise exposure or impact computer model currently used was constructed to determine the PE and ENI (LWP), and noise control costs for a sample of individual railyards, and then scale the results to a national level representing the total impact associated with approximately 4000 railyards identified (by U.S. DOT/FRA) in the United States.(4) The noise impact was determined for people in residential and commercial land use areas adjacent to and near individual railyards. This was done, basically by using the noise produced by groups of moving and stationary sources operating within the boundaries of a railyard facility, and the specific activity levels (numbers of noise events, or duration of operation) for each source at that railyard, to determine the noise exposure level (Ldn) generated. The land use patterns, population density, background noise level, and noise attenuation data for specific railyard location and type of noise source (or group) were incorporated in the analysis to determine the propagation pattern (variation of Ldn with distance) over the receiving properties (residential and commercial). The area within which the noise exposure (Ldn) exceeded 55dB was determined and thus the PE magnitude was obtained. Also, the number of people in incremental Ldn bandwidths multiplied by the impact factor for the corresponding Ldn value in each band was obtained and summed over all the increments to give the LWP value for the receiving area. The PE and LWP values for all the receiving areas at the railyard were then summed to give the total impact for the railyard facility.

In general, the basic elements and data requirements form the structure of the railyard noise impact computer model are indicated by Table 1.

Table 1. Basic Elements of the Railyard Noise Impact Model

Model Element	Input or Output Data
Railyard functional type	-Configuration, sub areas -dimensions (width, length)
Noise sources	-relative location in yard -type (moving, stationary) -operation patterns (dimensions) -source strength (noise level) -predominant spectra (frequencies) -noise event durations
Land Use patterns	-distribution and location of residential and commercial areas (receiving property) -dimensions of receiving areas -distances to receiving areas -land uses between railyard and receiving property -location of noise sources (groups) relative to receiving property
Population impacted	-average population density -receiving property population density
Railyard/Noise Source activity level	-average number of day and night events, or events per work shift -duration of operation per hour or work period
Noise exposure rating scale	-average day-night level (Ldn) -based on A-weighted sound level, dB
Propagation factors	-air and ground attenuation rate -residential building insertion loss -industrial building insertion loss
Noise generation equations	-Ldn, Lmax, Leq(1) max at base distance -Ldn, Lmax, Leq(1) max at receiving distance

Table 1. (Continued)

Model Element	Imput or Output Data
Noise propagation equations	- noise barrier attenuation - Ldn variation with distance
Noise impact determination	- Population Exposed (PE) - Level Weighted Population (LWP)
Noise reduction cost determination	- Barrier wall cost factors - Total cost for railyard
Railyard inventory	- Numbers of railyards in each functional category
Total National impact	- LWP and PE totals for sample railyards - LWP and PE scaled up to national level by ratio of total number to sample number of railyards - Total noise reduction costs from use of property line barriers

There are approximately 4000 rail carrier facilities in the U.S. which have been defined by DOT/FRA as railyards. Some of these railyard facilities are relatively large (50 to 100 parallel tracks, total complex 2 to 5 miles in length), and some are relatively small (a few tracks, and a few thousand feet in length). The largest yards may process a flow of 5000 railcars per day, while the very small yards move less than 50 railcars per day. For modeling purposes, it was appropriate and convenient to categorize these facilities by function into 4 major types.

- Hump classification railyards
- Flat classification railyards
- Industrial railyards
- Small industrial railyards

Classification means breaking apart the incoming trains into blocks of cars which are re-ordered according to destination and connected into strings of cars to make-up outgoing trains.

Hump classification yard configurations consist of a hill over which railcars are pushed by locomotives, and a bowl containing a fan of parallel tracks into which the railcars roll by gravity. Devices on the tracks called retarders act on the railcar wheels as they pass through to control their speed, and switches on the tracks fix the paths of the railcars.

Flat classification yards are operated by a number of locomotives called switch engines that pull, push, and cut loose railcars at each end of the yard to break up and re-form trains. Industrial and Small Industrial yards are also flat yards but are operated by a smaller number of switcher locomotives.

The predominant noise sources (operations) identified in railyard facilities and included in the model are listed in Table 2 according to yard type. Switch engines and in-bound and out-bound train operations are modeled as moving sources, while the remaining source types are stationary (grouped or virtual sources).

Table 2. Railyard Noise Sources

HUMP YARD - NOISE SOURCES:

- MR - Master Retarders (Includes Group Intermediate, and Track)
- HS - Hump Lead Switchers
- IR - Inert Retarders
- MS - Makeup Switchers
- CI - Car Impacts
- IL - Idling Locomotives
- LT - Locomotice Load Test
- RC - Refrigerator Cars
- IS - Industrial and Other Switchers
- OB - Outbound Trains (Road-Haul and Local)
- IB - Inbound Trains

FLAT CLASSIFICATION YARD - NOISE SOURCES:

- CS - Classification Switchers (includes industrial and other switchers)
- CI - Car Impacts
- IB - Inbound Trains
- OB - Outbound Trains (Road-Haul and Local)
- IL - Idling Locomotives
- LT - Load Tests
- RC - Refrigerator Cars

INDUSTRIAL AND SMALL INDUSTRIAL YARD - NOISE SOURCES:

- SE - Switch Engines
- CI Car Impacts
- IB - Inbound Trains (Local)
- OB - Outbound Trains (Local)

TOFC/COFC YARDS (ATTACHED TO SOME RAILYARDS) - NOISE COURCES:

- CT - Crane/Lift (Truck)
- GT - Hostler (Goat) Truck

Not all hump and flat yards will have parked refrigerator cars. In some cases, however, there may be refrigerator cars and idling locomotives parked in the smaller railyards (industrial, small industrial). Not all hump yards have inert retarders.

More detailed descriptions of the function and elements of the computer model are presented in the following sections.

1.2 Function and Logic of the Model

The railyard facility noise emission regulation model is designed to calculate the noise exposure levels generated and the rate of attenuation over the receiving areas, and then to compute the noise impact in terms of LWP and PE values for residential and commercial land use areas at individual railyards. In each case the baseline impact is calculated, and then noise barriers of various heights are added at appropriate railyard boundary locations to reduce the receiving property noise levels to selected alternative values (Ldn - 75, 70, 65, 60, and 55 dB). The costs for the required noise barriers are also computed by the program. The basic types of input data required and the results generated were indicated in Table 1.

In its simpliest form, the railyard noise impact model consists of three general sub-models:

- Noise Generation Model
    - Ldn for each noise source
    - Ldn for each group of noise sources

- Noise Propagation Model
    - Excess air and ground attenuation for each source
    - Insertion loss due to industrial land use
    - Insertion loss due to residential buildings
    - Insertion loss due to walls at railyard boundary
    - Total attenuation of Ldn with distance

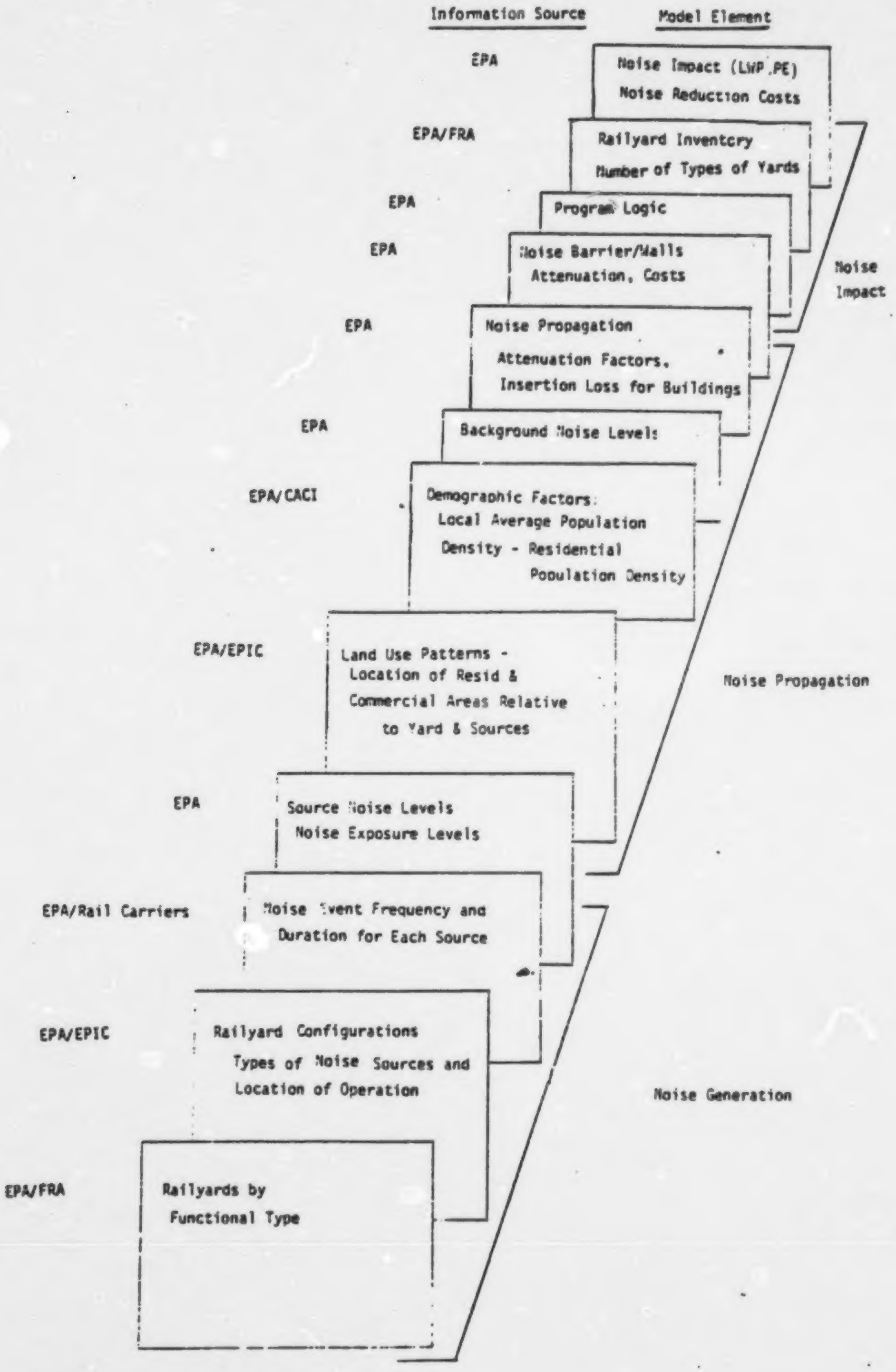
- Noise Impact Model
    - Integration to obtain PE and ENI (or LWP), and costs of noise barrier walls

These three models are combined in an integrated computer code.

A simplified view of the structure and elements of the model is provided by the diagram in Figure 1. A description of the input data and their requirements and generation will be discussed in detail in Section 2.2. The basic sources of the data are indicated in Figure 1. The Environmental Photo Interpretation Center (EPIC) analyzed photographic imagery in conjunction with U.S.G.S. maps for each sample railyard selected in order to determine the land use configuration around the railyard, and to indicate the locations of some of the railyard noise sources. Overlays on tracing paper were made to show the size, boundaries, and relative locations of areas interpreted as residential, commercial, industrial, agricultural, and undeveloped land uses. An example is shown in Figure 2. The population and other demographic variables in the area surrounding each sample railyard were obtained from census data analyses conducted by Consolidated Analyses Center, Inc. (CACI). The key railyard and source activity rates were obtained for many of the sample railyards from survey questionaires returned by the rail carriers. In general, the remainder of the data required were generated by the EPA from the literature on railyard operations, rail carrier noise sources, and rail facility noise surveys.

The basic logic for the model is indicated in Figure 3, and can be described as follows. For a given railyard type, type of sources operating, railyard traffic rate, and impact area the noise generation model first computes the Ldn value for each source at a reference distance of 100 ft., and then computes the Ldn for each source at DN, the distance to the near side of the impact area. The composite Ldn at DN is determined for the

Figure 1. Basic Structure of Railroad Noise Emission Regulation Impact Model


Information Source
Model Element
EPA
Noise Impact (LWP,PE)
Noise Reduction Costs
EPA/FRA
Railyard Inventory
Number of Types of Yards
EPA
Program Logic
EPA
Noise Barrier/Walls
Attenuation, Costs
Noise Impact
EPA
Noise Propagation
Attenuation Factors,
Insertion Loss for Buildings
EPA
Background Noise Levels
EPA/CACI
Demographic Factors:
Local Average Population
Density - Residential
Population Density
EPA/EPIC
Land Use Patterns -
Location of Resid &
Commercial Areas Relative
to Yard & Sources
Noise Propagation
EPA
Source Noise Levels
Noise Exposure Levels
EPA/Rail Carriers
Noise Event Frequency and
Duration for Each Source
EPA/EPIC
Railyard Configurations
Types of Noise Sources and
Location of Operation
Noise Generation
EPA/FRA
Railyards by
Functional Type

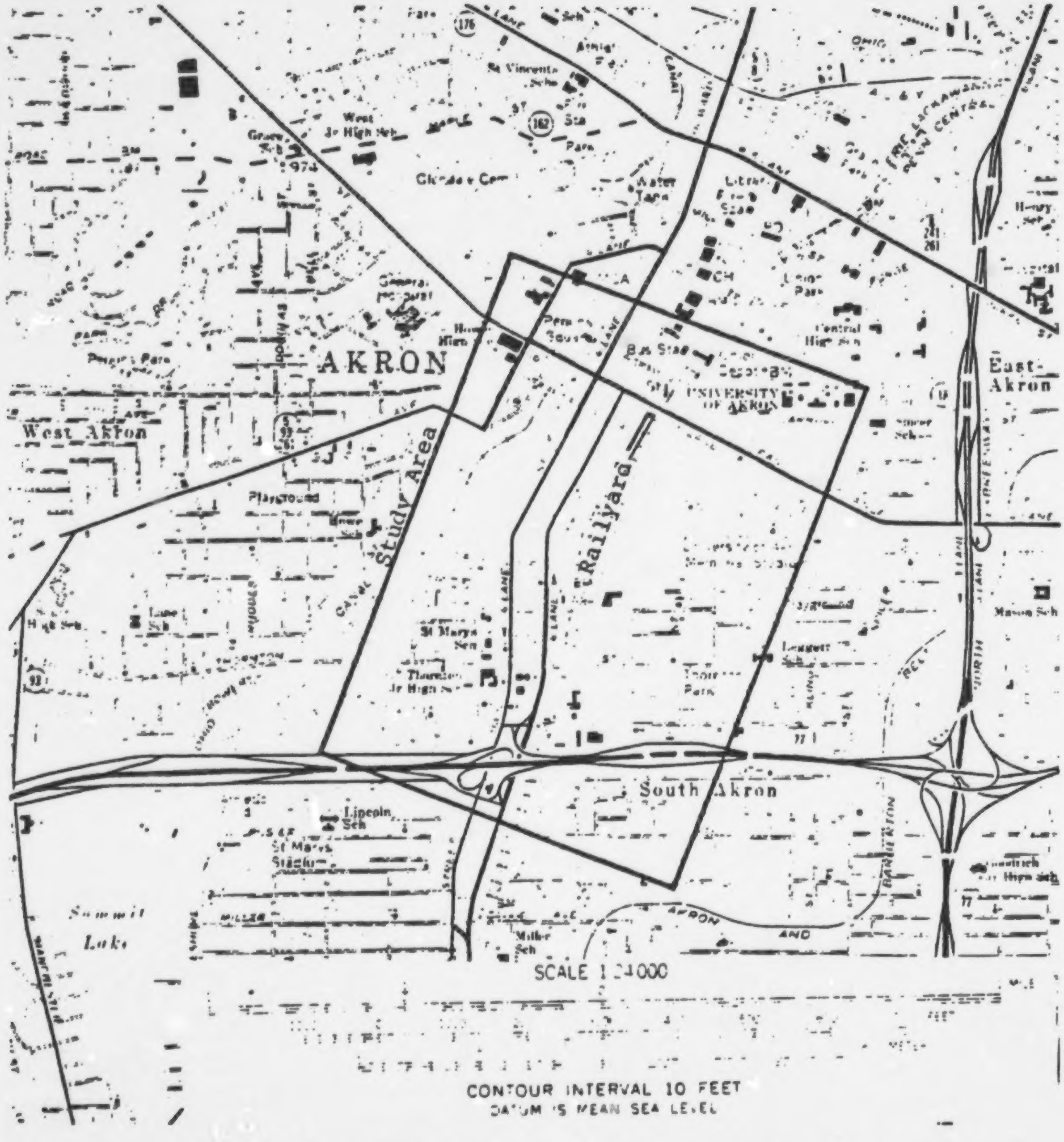
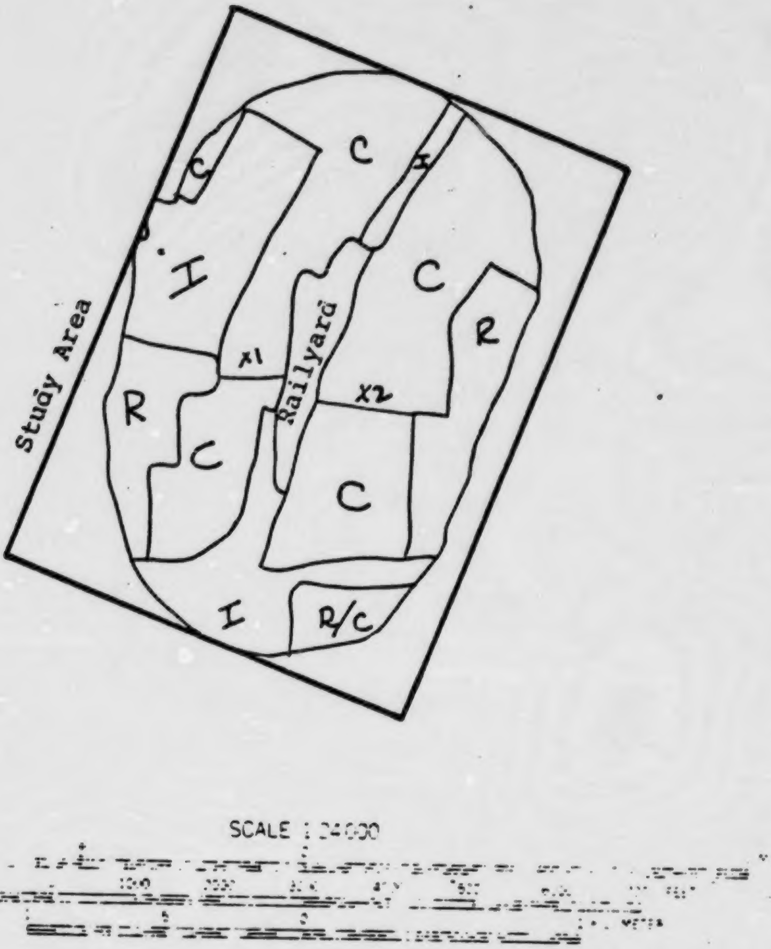

AKRON
West Akron
East Akron
South Akron
Study Area
Railyard
UNIVERSITY OF AKRON
St Vincents Sch
West Jr High Sch
Glendale Cem
Water Tank
General Hospital
Perkins Square
Bus Sta
Central High Sch
Playground
Lane Sch
St Marys Sch
Thornton Jr High
Leggett Sch
Lincoln Sch
St Marys Stadium
Miller Sch
Mason Sch
Summit Lake
CANAL
BARBERTON
AKRON AND
SCALE 1:24000
CONTOUR INTERVAL 10 FEET
DATUM IS MEAN SEA LEVEL

Figure 2(a): MILL STREET YARD, AKRON, OHIO, WITH STUDY AREA DELINEATED ON U.S.G.S. MAP

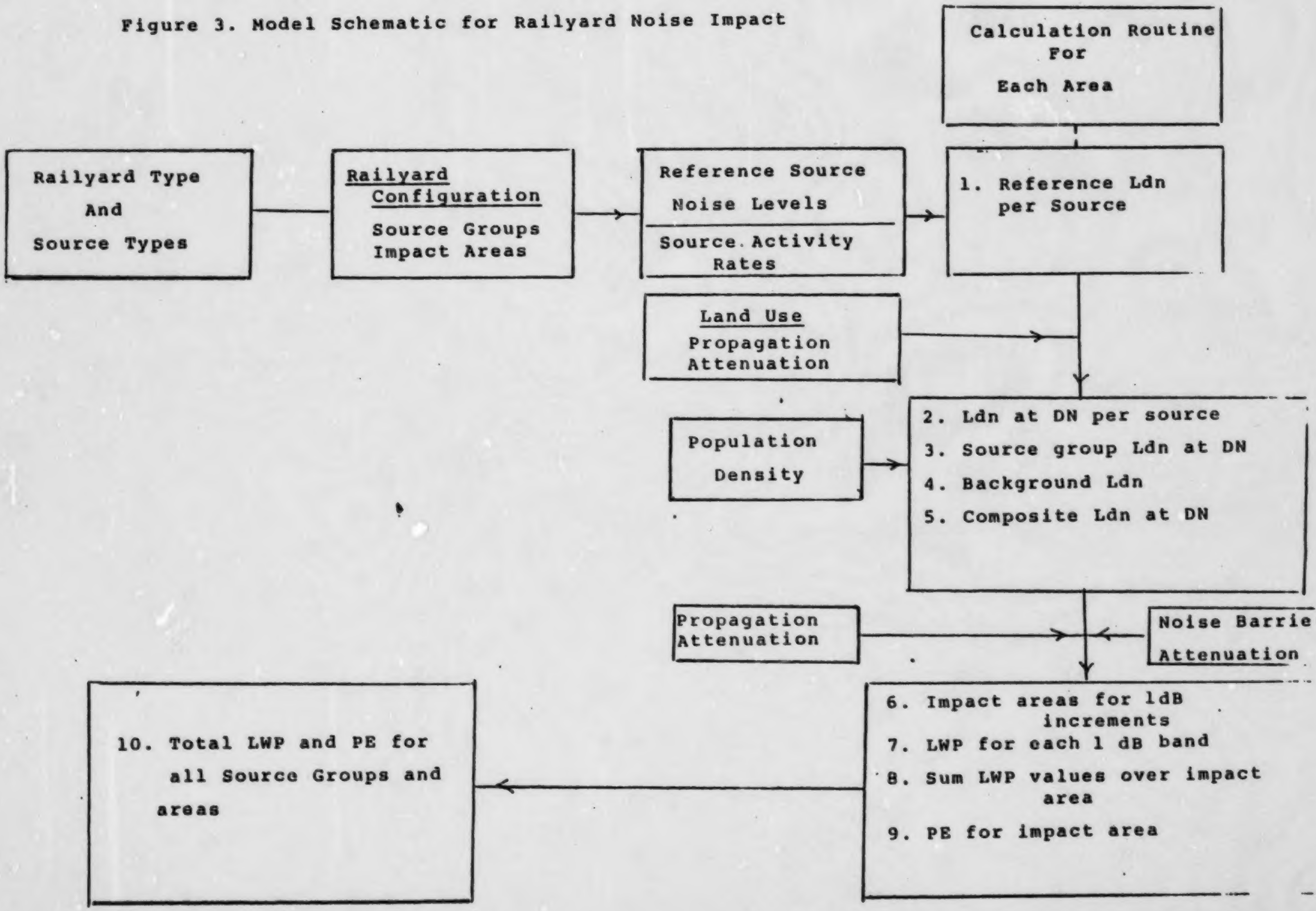
Reproduced from best available copy.


C
C
I
I
Study Area
C
R
X1
Railyard
X2
R
C
C
I
R/C
SCALE 1:24000

Reproduced from best available copy.

Figure 2(b): TRACING OVERLAY OF MILL STREET YARDS, AKRON, OHIO

Figure 3. Model Schematic for Railyard Noise Impact


Railyard Type And Source Types
Railyard Configuration
Source Groups Impact Areas
Reference Source Noise Levels
Source Activity Rates
Calculation Routine For Each Area
1. Reference Ldn per Source
Land Use
Propagation Attenuation
Population Density
2. Ldn at DN per source
3. Source group Ldn at DN
4. Background Ldn
5. Composite Ldn at DN
Propagation Attenuation
Noise Barrie
Attenuation
6. Impact areas for 1dB increments
7. LWP for each 1 dB band
8. Sum LWP values over impact area
9. PE for impact area
10. Total LWP and PE for all Source Groups and areas

source group, and combined with the background noise level. In the baseline case (no barrier wall) the composite noise level is then propagated across the impact area integrating the Ldn vs. distance relationship with the impact weighting factors and population density in 1dB increments to obtain the PE and LWP values. This procedure is followed for all impact areas and sources (groups) at the railyard, and the resulting PE and LWP values are summed to obtain the total impact.

For each of the alternative noise limits at the receiving properties, the various heights for a wall at the rail yard boundary necessary to reduce the baseline Ldn value to the desired values at the receiving properties are computed. The LWP and PE values are then calculated as discussed above.

1.3 Noise Generation, Propogation, and Exposure/Impact Equations

The basic algorithms and terms used to define or determine noise generation, propogation, and impact in the computer model are presented below:

1.3.1 Noise Generation

1. Reference Ldn at DO, (DO = 100 ft.) -

   (a.) For repeated single noise events all sources except IL, RC, and LT

   $$\text{Ldn (DO)} = \text{SEL} - 49.4 + 10 \log \left[(\text{ND}+10\text{NN})\ (\text{NL}/\text{NV})\right],$$
   when ND or NN > 0.

   Ldn (DO) = 0 when ND and NN = 0.

   The term (NL/NV) represents the number of locomotives at each virtual source (e.g., if there are 3 virtual sources and 6 locomotives, then the effective number of locomotives at each virtual source is:

   $$\frac{6}{3} = 2).$$

   (b.) For quasi - continuous noise events (IL, RC, and LT)

   $$\text{Ldn (DO)} = \text{SEL}-13.8 + 10 \log (\text{NH} \times \text{NU1} + \text{NH2} \times \text{NU2} + 10\text{NH3} \times \text{NU3});$$

   SEL = LEQ (1), and

   NH1, NH2, or NH3>0.

   Ldn (DO) = 0, when NH1, NH2, and NH3 = 0.

2. Activity Rates

   $$\text{ND} = \text{NP} \times \text{NED} \times \text{NES} \times \text{EP}$$

   $$\text{NN} = \text{NP} \times \text{NEN} \times \text{NES} \times \text{EP}$$

3. Terminology -

   Ldn = Day-Night Average Noise Level

   SEL = Reference Single Event Level $(10 \log \int_0^T 10^{L(t)/10} dt)$

   LEQ (1) = Reference Equivalent Noise Level for 1 hour duration

   ND = Total Number of Day-time events (7am - 10pm)

   NN = Total Number of Night-time events (10pn - 7am)

   NL = Number of Locomotives

   NV = Number of Virtual sources

NH1 = Number of Hours operating during first shift

NU1 = Number of Units operating during first shift.

NH2 = Number of hours operating during second shift

NU2 = Number of Units operating druing second shift

NH3 = Number of Hours operating during third shift

NU3 = Number of Units operating during third shift

NP = Number of Pass-bys per event (moving sources)

NED - Number of sources or events, Day-time

NEN = Number of sources or events, Night-time

NES = Number of Events per Source

EP = Event Probability

4. Reference LMAX and LEQ MAX (at DO).

(a.) For repeated single noise events

$$\mathrm{LMAX} = \mathrm{LMAX}\ (\mathrm{DO}) + 10 \log \mathrm{NL}$$

LEQMAX = Larger of Day LEQ and Night LEQ (1)

$$\text{Day LEQ (1)} = \mathrm{SEL} - 47.3 + 10 \log \left[\mathrm{ND} \left(\frac{\mathrm{NL}}{\mathrm{NV}} \right) \right]$$

$$\text{Night LEQ (1)} = \mathrm{SEL} - 45.1 + 10 \log \left[\mathrm{NN} \left(\frac{\mathrm{NL}}{\mathrm{NV}} \right) \right]$$

(b.) For quasi - continuous noise events (IL,RC,and LT)

$$\mathrm{LMAX} = \mathrm{LMAX}\ (\mathrm{DO}) + 10 \log (\mathrm{NUX})$$

$$\mathrm{LEQMAX} = \mathrm{LEQ}\ (1) + 10 \log (\mathrm{NUX})$$

NUX = Larger of NU1, NU2, or NU3

1.3.2 Noise Propagation

5. Ldn at Receiving Property (DN).

$$\text{Ldn (DN)} = \text{LDN(DO)} - \text{ALPHAG} \times (\text{DN}-\text{DO}) - \text{AI} - 10 \log \left(\frac{\text{DN}}{\text{DO}}\right)^{N}$$

DN = Distance from source to near side of receiving property

ALPHAG = Extra Air and Ground Attenuation Coefficient

AI = Insertion loss due to industrial buildings

N = 1 for moving source
2 for stationary source

6. LMAX and LEQMAX at Receiving Property (DN).

$$\text{LMAX (DN)} = \text{LMAX} - \text{ALPHAG} \times (\text{DN}-\text{DO}) - \text{AI} - 10 \log \left(\frac{\text{DN}}{\text{DO}}\right)^{N}$$

$$\text{LEQMAX(DN)} = \text{LEQMAX} - \text{ALPHAG} \times (\text{DN}-\text{DO}) - \text{AI} - 10 \log \left(\frac{\text{DN}}{\text{DO}}\right)^{N}$$

7. Noise Barrier (Wall) Attenuation

$$AW = 5 + 10 \log \left(\frac{\sqrt{2\pi N}}{\tanh \sqrt{2\pi N}} \right)^{y}$$

$N = 2\delta / \lambda_0$.

λ_0 = wave length for predominant frequency (f_0)

δ = propagation path distance increment due to barrier

y = variable (1 to 2), dependent on type of source and configuration factors*

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*For this model a conservative value of 1 was selected for y. This partially accounts for the effects of finite barrier lengths, and compensates for the fact that extra air and ground attenuation has been accounted for elsewhere in the propogation equations.

$A = \sqrt{(H_w - H_s)^2 + (DR - DB)^2}$

$B = \sqrt{(H_w - H_r)^2 + DB^2}$

$C = \sqrt{(H_s - H_r)^2 + DR^2}$

H_w = wall height, ft. (maximum allowable H_w = 30 ft.)

H_s = source height, ft.

H_r = receiver height, ft.

DB = distance from railyard boundary to receiving property, ft.

DR** = distance from source to receiving property, ft.

**When DB < 50, DR = DN + (50-DB), DB = 50
When DB $\geq$ 50, DR = DN

8. The following restrictions hold for AW -
   a. When $H_s = H_r$ and $H_w < H_s$: AW = 0
   b. When $H_s = H_r$ and $H_w = H_s$: AW = 5
   c. When $H_s > H_r$ and $H_w < h + H_r$:AW = 0
   d. When $H_s > H_r$ and $H_w = h + H_r$: AW = 5
      $h = (H_s - H_r)\ DB/DR$
   e. When $H_r > H_s$ and $H_w < h + H_s$: AW =0
   f. When $H_r > H_s$ and $H_w = h + H_s$: AW = 5
      $h = (H_r - H_s)\left(\frac{DR-DB}{DR}\right)$

These restrictions result in AW = 0 when the wall is not high enough to break the line-of-sight between the source and the receiver, and AW = 5 dB when the wall height is just high enough to break the line-of-sight.

8. Ldn at any distance (D) beyond receiving property line.

$$Ldn\ (D) = Ldn\ (DN) - AT - GALPHAG \times (D-DN) - 10 \log \left(\frac{D}{DN}\right)^N$$

GALPHAG = grouped source air and ground absorption coefficient (db/ft.).

AT = Total insertion loss due to noise barrier, industrial land, and residential/commercial buildings (dB).

N = 1 for moving source
2 for stationary source

9. Total insertion loss, AT.

AT = f (AW, AI, AR), dB

AW = noise barrier wall insertion loss, dB

AI = industrial building insertion loss, dB

AR = residential/commercial building insertion loss, dB

Baseline (No wall at railyard boundary, AW=0)

Case (a) When AI = 0, $A_T = AR$

Case (b) When AI > 0, $A_T = AI + \frac{AR}{2}$

Wall at Railyard Boundary (AW > 0):

Case (c) When AI = 0, $A_T = AW + AR/2$

Case (d) When AI >0,

$$A_T = AW + AI + AR/_4$$

---

*Source group composite Ldn

1.3.3 Noise Exposure/Impact

Improvements in public health and welfare are regarded as benefits of noise control. Public health and welfare benefits may be quantified both in terms of reductions in noise exposures and, more meaningfully, in terms of reductions in adverse effects. The model first quantifies community exposure to rail facility noise (number of people exposed at different noise levels), then translates this exposure into a community impact measure. The noise exposure/impact scale is based on the general adverse response to environmental noise, and indicates the magnitude of stress response and the severity of activity interference.

In general, reducing rail facility noise levels at residential and commercial land uses is expected to produce the following benefits:

1. Reduction in railyard noise levels and associated cumulative long-term impact upon the exposed population.
2. Fewer activities disrupted by individual, intense noise or intruding noise events.
3. General improvement in the quality of life, restoring quietness as an amenity resource.

The railyard noise impact model quantifies the noise levels in residential and commercial areas, and numbers of residents living within each different level of noise environment. This provides a measure of the community's general adverse response to rail facility noise. The analyses were conducted on the basis of population information which indicated the local average population densities near railyards, but with no differentiation between residential and commercial land use. This, in effect, quantified the impact on the residents of the area regardless of whether they participate in residential or commercial activities.

The general measure for environmental noise used by the EPA is the equivalent or average A-weighted sound level (Leq), in units of decibels. This indicator correlates well with the overall long-term effects of noise on the public health and welfare.

When expressed in terms of an A-weighted sound level, L(t), the equivalent sound level (L_{eq}) is expressed by:

$$L_{eq} = 10 \log_{10} \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t^2} 10^{L(t)/10} \, dt \right]$$

where, in general, $L(t) = 10 \log_{10} \left[\frac{p(t)}{p_o} \right]^2$

The cumulative impact of noise on people is assessed in terms of the day-night sound level (L_{dn}) which is a noise rating scale developed by the EPA. L_{dn} is used as a rating scale for the daily (24-hour) sound exposure. It incorporates a weighting applied to nighttime noise levels to account for the increased sensitivity or reaction of people to noise intrusion at night. Thus, L_{dn} is defined as the equivalent sound level during a 24-hour period, with a 10 dB weighting applied to the noise levels for the noise events during the nighttime hours of 10 P.M. to 7 A.M. This may be expressed by the following equation:

$$L_{dn} = 10 \log_{10} \frac{1}{T} \left\{ \int_{t_1}^{t_2} 10^{L(t)/10} \, dt + \int_{t_2}^{t_3} 10^{[L(t)+10]/10} \, dt \right\}$$

where $T = t_3 - t_1$, t_1=7 A.M. on 1st day, t_2=10 P.M. and t_3 = 7 A.M.

For the purposes of this model, noise impact criteria presented in the EPA Levels Document are used. When the outdoor level of L_{dn}=55 dB (which is identified in the EPA Levels Document as requisite to protect the public health and welfare) is met, no adverse impact in terms of general annoyance and community response is assumed to exist on a statistical basis.

For $L_{dn} > 55$, a function for weighting the magnitude of noise impact with respect to general adverse response (annoyance) has been developed by the EPA. This function, normalized to unity at L_{dn} = 75 dB, expresses the expected fractional impact, W (L_{dn}), in accordance with the following relationship:

$$10. \quad W(L_{dn}) = \begin{cases} .05(L-C) & \text{for } L > C, \\ 0 & \text{for } L < C. \end{cases}$$

L is the observed or measured L_{dn} of the environmental noise, and in this study model the criterion level C is L_{dn} = 55 dB.

The total impact of railyard noise can then be expressed in terms of both extensiveness (i.e., the number of people impacted) and intensiveness (the severity of impact) by multiplying the W (L_{dn}) value by the number of people (P) exposed for the corresponding noise level and area under consideration.

For an increment of area, then, the noise level weighted population (LWP), or the number of people who are considered 100 percent affected, is given by:

$$11. \quad LWP_i = W_i\ (L_{dn}) \times P_i$$

Since the L_{dn} from a given source varies with distance, the $W(L_{dn})$ value will vary with distance also, and the total impact (LWP) is obtained by integration or summation of the LWP values in the successive increments of area outfrom the source. In the general form, the total equivalent impact rating is:

12. $$LWP = \sum_i P_i \times W_i\,(L_{dn})$$

More specifically, the LWP calculation is made on the basis of successive 1 dB decrements in L_c, where L_c is the composite L_{dn} value for the grouped source noise level and the background noise level, subject to certain restrictions explained subsequently.

Source group $L_{dn} \equiv L_G = 10 \log \left(\sum_j 10^{L_{dn_j}/10}\right)$, dB;

$L_{dn_j} = L_{dn}$ value for each source,

13. L_c, composite environmental $L_{dn} = 10 \log \left(10^{L_G/10} + 10^{L_{BG}/10}\right)$, dB:

and L_{BG} = background (non-railyard source) L_{dn}, dB

14. $L_{BG} = 22 + 10 \log \rho$, dB; when $\rho < 1585$

$L_{BG} = 54$ dB, when $\rho \geq 1585$

ρ = local average population density $\left(\frac{\text{people}}{\text{sq. mi.}}\right)$

15. Restrictions on L_G and L_c:

$L_G \geq L_{BG} - k$, $k \leq 6$, and

$L_c \geq 55$

These restrictions prevent L_G from decreasing to less than 6 dB below L_{BG}, and thus prevent L_c from decreasing to less than 55 dB.

16. Average L_c for each incremental area in computing LWP_i

$$W_i\ (Ldn) \equiv W_i\ (\bar{L}_c)$$

$$L_{c_{i+1}} = L_{ci} - 1\text{dB, and}$$

$$\bar{L}_{ci} = \frac{L_{c_i} + L_{c_{i+1}}}{2}\ \text{dB}$$

$$W_i\ (\bar{L}_c) = \left(\frac{\bar{L}_{c_i} - 55}{20}\right)$$

17. Incremental area and population

The incremental areas (A_i) are either rectangular strips (for moving sources) or angular sectors between successive segments of a circle (for stationary sources).

Stationary Sources

$$A_i = \frac{D_{i+i}^2}{2} \cos^{-1} \left(\frac{D_1}{D_{i+1}}\right) - D_1 \sqrt{D^2_{i+i} - D^2_1}$$

$$- \left(\frac{D_i^2}{2} \cos^{-1} \left(\frac{D_1}{D_i}\right) - D_1 \sqrt{D^2_i - D^2_1}\right)$$

Moving Sources

$A_i = d(D_{i+1} - D_i)$, d = length of receiving property,

D_i = distance from source to near side of area increment,

D_{i+1} = distance from source to far side of area increment.

The increment area population is computed according to:

$P_i = \rho_r A_i$, where

$\rho_r = \rho / r$, and

r = residential and commercial land use factor, or fraction ($r \leq 1.0$)

Thus, starting at DN (or $D_i = D_1$) and continuing across the receiving property, increments of area are defined (D_i is computed) such that $\overline{L}_{ci}$ decreases 3 dB for each successive area increment until either the far side of the property is reached or L_c decreases to 55 dB. $W_i(\overline{L}_c)$ and LWP_i are computed for each area increment, and the LWP_i values are summed to obtain the total LWP value. Also, the total area in which $L_c = 55$ dB is multiplied by ρr to obtain the Population Exposed (PE) value.

18. Total National Impact

When LWP values have been computed for a sample of railyards for one of each of the 4 types of railyards, the LWP associated with all the railyards in the United States for the particular type(s) is estimated according to:

$$LWP_s = \sum_k LWP_k \text{ , and}$$

$$LWP_t = LWP_s \times \frac{N_t}{N_s} \text{ , where}$$

LWP_s = total LWP for the sample railyards (in a particular type),

N_s = number of railyards in the sample,

N_t = estimated number of railyards in the U.S. for the particular type.

1.4 Benefit and Cost Measures

The benefits associated with alternative regulatory levels for railyard facility noise emission limits are measured in terms of the reduction in the ENI (or LWP) or PE achieved. The computer model calculates the difference between the baseline (i.e., no noise barriers at the railyard boundary) ENI value and the resulting ENI value after different height walls are considered at the railyard boundary to reduce the noise levels to the alternative regulatory levels (L_{dn} = 75, 70, 65, and 60 dB). Thus, the output data includes the ENI reduction (DENI) associated with each regulatory level for each railyard analyzed.

The computer program also computes the estimated costs for construction of the walls at the railyard boundary to attenuate the railyard source noise levels to the alternative regulatory levels. The noise barrier costs are determined according to:

$$\$ \text{ cost of wall} = \text{length (ft.)} \times \text{height (ft.)} \times c_i$$

$$c_i = \frac{\text{cost}}{\text{unit area}} (\$/\text{ft}^2).$$

This cost, c_i, is assumed to be $10 per sq ft.

2.0 Input Data Requirements

2.1 Introduction

Two categories of functional input data are required for the operation of the computer program. Fixed (or static) data are required that define the railyard and noise source type, source operation characteristics, basic activity assumptions, and the physics of noise propagation. Variable (or dynamic) data are required to define the configuration of the specific railyard, the receiving property locations, size and population, and the noise event rates for the specific railyard and sources.

The fixed data include reference noise levels (L_{max} and L_s) for all the noise sources, the distance from the source to reference location, attenuation factors, number of sources and source groups, and activity factor assumptions. The variable data include distance from sources to receiving properties, dimensions of receiving properties, travel distance for moving sources, propagation attenuation factors, number of noise events or hours of operations for each source, and number of noise sources.

2.2 Source Noise Levels

The reference average noise levels* used in the noise impact health and welfare model are summarized in Table 3. The bases for determining the average noise level for each type of source are presented below. Data sources are specified in the reference section.(6-13) More detailed information on the derivation of the average source noise levels can be found in Reference 17, Appendix L.

Master/Group Retarders

Average Maximum Noise Level:

The references (numbers in parentheses) and data shown below were used to obtain the baseline average maximum noise level for master and group retarders. All measurements were at or normalized to a distance of 100 ft. (30m).

(1) a. L_{max} energy ave. = 116 dB; 58 measurements.
b. L_{max} energy ave. = 111 dB; 37 measurements.
(6) L_{max} energy ave. = 108 dB @ 100 ft (30 m); 38 measurements.
(9) a. L_{max} energy ave. = 109.5 dB; 113 measurements.
b. L_{max} energy ave. = 108.5 dB; 164 measurements.
(1,6,9) Composite average L_{max} = 111 dB; 410 measurements.

Average Single Event Level ($\bar{L}_s$):

A sample noise-time history indicated durations of 1.5 to 2 sec between the 20 dB down points for clearly definable events.(6) The typical L_{max} = 110 dB at 100 ft with a 10dB down point duration (t_{10}) of 1 sec and a typical L_s of 107 dB. This implies that $\Delta t_{eff} = 0.5$ sec since:

$$L_s = L_{max} + 10 \log \Delta t_{eff}.$$

A few other data indicated a typical retarder squeal (at 100 ft or 30 m distance) could be represented by an equilateral triangle time-history with a maximum level of 110 dB and a duration of 3.6 sec for the 30 dB down points (t_{30}).(6,9) This also results in $\Delta t_{eff} = 0.5$ sec.

Additional data on retarder noise events were obtained during noise measurements at railyards conducted for the EPA in 1978.(13)

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*A-weighted sound pressure level, dB re. $2X10^{-4}$ dynes/cm^2.

Table 3

SOURCE NOISE LEVEL* SUMMARY

Noise source	Number of Measurements	L_{max}, dB;	Leq (Work cycle), dB;	L_s or [Leq(1)], dB
Master Retarder: Group, Track and Intermediate	410	111	-	108
Inert Retarder	96	93	-	90
Flat Yard Switch Engine	Ref. 18	90	77	94 (4 MPH)
Hump Switch Engine, (Constant Speed)	Ref. 6	90	78	95 (4 MPH)
In-or Out-bound Locomotive	Ref. 6	90	78	95 (4 MPH)
Idling Locomotive	27 55	65 67	(<2500 HP) (>2500 HP)	[66]
Car Impact	164	99	-	94
Refrigerator Car	23	73	67	[67]
Load Test (High Throttle)	59	90	87	[87]
Crane Lift	Ref. 19	83	79	106.5
Hostler truck	Ref. 19	82	65	94.5

* A-weighted Average at 100 ft.

Analytical evaluation of the 1978 measurement data indicate typical Δt_{eff} values in the 0.5 sec range.(17) Thus, at 100 ft (30 m) distance from the retarder, the typical or average L_s value is 108 dB.

Inert Retarders

The energy average maximum level (L_{max}) for the 96 data points was 93 dB (@ 100 ft.).(6)

Since there were no data available on inert retarder noise event durations, it was assumed that Δt_{eff} = 0.5 sec. Thus the reference L_s was 90 dB.

Flat Yard Switch Engines

Maximum noise levels at 100 ft. (30 m) for 30 events during acceleration passbys ("kicking" railcars) were in the range 73 to 92 dB, with an energy average level of 83 dB.(6) However, more recent data indicated a work cycle average level of 77 dB, and an average speed of 4 mph.(18) Therefore(5) -

Reference $L_s = 77 + 10 \log (\pi \, D/V) = 94$ dB, where
$= 100$ ft., and $V = 5.9$ ft./sec.

Hump Switch Engine

Only a few data samples were available to indicate the typical noise level for hump lead switch engine passbys.(6) These data indicated that Leq was in the 76 to 80 dB range at 100 ft (30 m). Therefore, an Leq = 78 dB was assumed for the noise impact model. Thus(5)

Reference $L_s = 78 + 10 \log (\pi \frac{D}{V}) = 95$ dB, where
$D = 100$ ft., and $V = 5.9$ ft./sec.

Idling Locomotives

Two references contained numerous measurements of noise levels from a wide variety of types and sizes (HP) of rail locomotives at the stationary idle (throttle setting 0) condition.(2,6) The measurements were obtained at distances of 50 to 150 ft (15.2 to 92 m) in railyards under a variety of operating conditions (including load tests, special tests near repair shops and groups of idling locomotives). These data were examined and, where required, normalized to the noise level of one locomotive at a distance of 100 ft (30 m). In those cases where the measured level was due to a line or group of locomotives, a standard analytical procedure was used to estimate the average level for one locomotive.(6) One of the references presented data for "road engines" and "switch engines" without defining either type of locomotive.(6) The other reference listed the power rating (HP) of the locomotives for which noise levels were measured.(2)

In the railyard noise impact model, it was assumed that switching operations were performed by a 50/50 mixture of locomotives above and below 2500 HP. Therefore, the Leq(1) value used in the model for an idling locomotive was 66 dB.

Load Cell Operations

Noise measurement data for locomotives operating in a stationary condition at high throttle settings were available from 4 references.(1,2,6,9) The locomotives were operating under either a self-load condition or at a load test cell facility. The majority of the data samples (51 out of 59) were contained in one of the references.(2) The size of the locomotives ranged from 1500 to 3600 Hp, and the noise levels at 100 ft (30 m) ranged from 84 to 94 dB. The resulting energy average noise level at 100 ft (30 m) was 90 dB. However, to account for a mixture of low and high throttle settings, an Leq(1) = 87 dB was assumed.

Refrigerator Cars

Noise levels from the diesel engine powered cooling units on refrigerator cars are a function of engine speed and which side of the car the measurement is being made. The cooling units typically operate at either low or high engine speed. Several references are available which present a total of approximately 100 samples of refrigerator car noise levels.(6,12,17)

However, much of the data is not defined relative to both engine speed and side of railcar (engine vs. condenser). Therefore, only those noise data (about 23 samples) for which specific operating conditions and measurement locations were known were used to derive the representative average noise level for refrigerator cars.(6,17) The weighted (energy) average for both sides at each throttle setting was calculated since the refrigerator cars are likely to be randomly oriented in the railyards, and thus it was assumed that it would be equally likely (over the total number of railyards) for the receiving property areas to be subjected to the high and low noise sides. Also, the recent references indicated that high engine speed operation typically occurred for only 10 minutes per hour.(12) Thus, the weighted energy average level for both speeds and both sides was 73 dB at 50 ft (15 m). The reference level thus used in the noise impact model was Leq (1) = 67 dB at 100 ft (30 m).

Railcar Coupling (Impact)

Several references provided noise level data for railcar coupling impact events.(6,9,11) Two of the references which were initially available did not include either coupling speed data correlated to the noise level, or noise event durations from which SEL values could be determined.(6,9) However, other references provided impact noise levels (L_{max} and L_s) correlated to coupling speeds, and indicated the probability distribution for coupling speeds.(10,11) Assuming that the noise level and speed distributions would hold for all railyards, it was possible to calculate the expected energy noise level for car impact events. Essentially, the expected level is the integral of the product of the noise-speed and speed-probability functions. The basic data used for this determination consisted of 31 samples of L_{max} and L_s values for coupling noise(11), and 61,000 samples of car coupling speeds.(10)

The expected noise level values were:

Max L_{exp} = 98.8 dB at 100 ft (30.5 m).

$L_{s\ exp}$ = 94 dB at 100 ft (30.5 m).

In addition, two possible impact noise control options were considered - limiting coupling speeds to 6 MPH, or to 4 MPH. Expected noise level values for these cases were determined by assuming that for the 6 MPH speed limit case, all couplings above 6 MPH would be redistributed into the 5 to 6 MPH interval. And for the 4 MPH speed limit case, all couplings above 4 MPH would be redistributed into the 3 to 4 MPH interval. The results were:

- 6 MPH Speed Limit, Max L_{exp} = 97.3 dB
  $L_{s\ exp}$ = 92.0 dB
- 4 MPH Speed Limit, Max L_{exp} = 91.7 dB
  $L_{s\ exp}$ = 85.8 dB

TOFC/COFC Yard Noise Sources

It was determined by noise survey data that the trailers-on-flat-car and container-on-flat-car areas at railyards could be represented by two predominant noise sources - diesel powered cranes (crane-lifts) and trucks (hostler or goat trucks).(19) The average noise levels at 100 ft. (30 m), and durations per work cycle were:

Crane-lift Lmax = 83 dB
Leq (work cycle) = 79 dB
Work cycle duration = 9 min.
Ls (work cycle) = 106.5 dB

Goat Truck Lmax = 82 dB
Leq (work cycle) = 65 dB
Work cycle duration = 15 min.
Ls (work cycle) = 94.5 dB

2.3 Fixed Input Data

The fixed input data are shown in Table 4. The fixed input data remain constant for all the corresponding yards unless new data become available or new assumptions are made. Then, of course, the values of the input parameters can be changed accordingly. The source related activity constants (NP, NL, NV, etc.) were derived from the railyard data base evaluations. For example, the number of pass-bys (NP=2) per each switch engine operation is based on the logic that each receiving property will be exposed to one noise event as the switcher moves by to pick up a block of railcars, and then a second noise event when the switcher returns with the railcars to conduct the classification operation. However, it is assumed that the receiving properties will be exposed to only one noise event (NP=1) for each inbound and outbound train operation. In the case of stationary sources, NP is not applicable, and a value of 1 (no effect) is entered in the noise generation equation. In the case of railcar coupling noise events (or impacts, CI) the number of virtual sources (NV) is assumed equal to 2 for hump yards and 4 for flat classification yards so that there are effectively 2 or 4 locations, 1 or 2 at each end of the classification area, where the noise events occur. In conjunction with car impacts it is also assumed (based on measured data) that in general only one-half of the cars classified result in a noise event and thus the noise event probability (EP) is 0.5. In the case of master/group retarder (MR) noise events, the railcars pass through 2 (or more) retarder stages, but produce a noise event only one-half the time - thus the number of noise events per railcar classified (NES) is 2 and the noise event probability (EP) is 0.5. In the TOFC/COFC areas the goat or hostler truck (~~H~~CT) works two cycles (NES=2) for each flat railcar (two trailers per flat car), and the crane lift (CT) works 4 cycles (NES=4) for each flat railcar loaded.

TABLE 4. Fixed Input Data for Railyard Noise Impact Model
Noise Source Data

INPUT DATA PARAMETER										
NOISE SOURCE	LMAX* (dB)	LS* (dB)	NP	NL	N	NV	NES	EP	ALPHAG (dB/FT)	DO (FT)
HS	90	95	2	1	1	1	1	1	.001	100
MS	90	94	2	2	1	1	1	1	.001	
IS	90	94	2	1	1	1	1	1	.001	
CS	90	94	2	1	1	1	1	1	.001	
IB	90	95	1	3(1)	1	1	1	1	.002	
OB1	90	95	1	3(2)	1	1	1	1	.002	
OB2	90	95	1	1	1	1	1	1	.002	
MR	111	108	1	1	2	1	2	0.50	.010	
IR	93	90	1	1	2	1	1	0.85	.010	
CI	99	94	1	1	2	2 (3)	1	0.50	.005	
IL	66	66	NA	NA	2	NA	NA	NA	.0025	
RC	73	67	NA	NA	2	NA	NA	NA	.0035	
LT	90 (4)	87(4)	NA	NA	2	NA	NA	NA	.0020	
GT	82	94.5	1	1	2	1	2	1	.0020	
CT	83	106.5	1	1	2	1	4	1	.0020	

* Reference (at 100 ft.)

(1) 1 for Industrial and Small Industrial Yards

(2) 1 for Small Industrial Yards

(3) 4 for Flat Classification Yards

(4) These values are reduced by 12 dB in the model when it is assumed that the source standard for load test cells requires a noise absorbing barrier to be used at the test cell site.

2.4 Source Noise Attenuation Factors

Divergence Loss

The reduction of noise with distance from the source because of divergence loss for stationary (individual and grouped) sources in the railyards is a function of 20 $\log_{10}$ (distance ratio) assuming that the sources radiate in the normal hemispherical pattern. Therefore -

Stationary Source: $L_{dn}(D_2) = L_{dn}(D_1) - 20 \log (\frac{D_2}{D_1})$.

In the case of the moving sources, e.g., switch engines, L_{dn} is developed from SENEL per pass-by and the number of pass-by events. At a particular distance from the sources the SENEL value is a function of the speed of the source and the maximum noise level (L_{max}) during the pass-by.(5)

$$SENEL_1 = L_{max_1} + 10 \log \left(\pi \frac{D_1}{V} \right)$$

where:

D_1 = distance from source to observer (m), and

V = source speed (m/sec).

Then at any other distance D_2 it can be shown that -

$$SENEL_2 = SENEL_1 - 10 \log \frac{D_2}{D_1}, \text{ and}$$

Moving Source: $L_{dn}(D_2) = L_{dn}(D_1) - 10 \log (\frac{D_2}{D_1})$.

Air and Ground Absorption

During propagation, the noise energy is also absorbed in the air and on the ground surfaces. The air and ground absorption rates are dependent mainly on the predominant frequencies in the noise spectrum and also the relative humidity and air temperature. Nominal expressions for air and ground attenuation developed by DOT, for an average day (60°F and 65% relative humidity) are:

$$A_{air} = \frac{2fd}{10^6}$$

$$A_{ground} = 10 \log_{10} \frac{fd}{4x10^5} \text{ , for } fd > 4x10^5,$$

$$A_{ground} = 0, \text{ for } fd \leq 4x10^5,$$

where:

A = attenuation, dB

f = sound frequency, Hertz, and

d = distance from source, feet.

However, since the noise model must compute L_{dn} values, and since the L_{dn} noise rating scale is based on A-weighted sound levels, it is more convenient to use a combined air and ground attenuation factor representing the attenuation of the A-weighted noise levels with distance. For each type of source the air and ground attenuation was calculated for 100 to 2000 foot (30 to 610 m) distance using the center frequency of each octave band for the f value in the equations given above. The A-weighted level at each distance was then computed from the correspondingly attenuated octave band noise levels, and the differences between the levels at the selected distances were used to determine the average extra attenuation (A_{a+g}) in dB attributable to air and ground absorption. The resulting combined air and ground absorption coefficients are shown for each noise source type in Table 5.

Table 5. COMBINED AIR AND GROUND ABSORPTION FOR MAJOR RAILYARD NOISE SOURCES

Noise Source	Combined Air and Ground Absorption Coefficients, ALPHAG (dB/ft)*	
Retarder	0.01 (dB/ft)	0.033(dB/m)
Switch Engine	0.001	0.0033
Car Impact	0.005	.0164
Idling Locomotive	0.0025	.0082
Locomotive Load Test	0.002	.0066
Refrigeration Car	0.0035	.0115
Road-Haul Locomotive	0.002	.0066
Crane-lift	0.002	.0066
Hostler Truck	0.002	.0066

*Based on A-weighted SPL

However, in general, the noise impact results from either groups of stationary or moving sources. The average absorption coefficients assumed for mixed types of stationary and moving sources are shown in Table 6.

Table 6. Average Propagation Attenuation Coefficient for Grouped Sources

Group Type	GALPHAG (dB/ft.)
Moving Source Group	0.002
Stationary Source Group	0.005

2.5 Noise Barrier Parameters

The noise attenuation in a receiving property due to placement of a wall at the railyard boundary is determined from the equations shown in subsection 1.1.3.2, Noise Propagation, item 7. The dominant sound frequency and height above ground for each type of noise source are shown in Table 7. The receiver height (H_r) used was 5 ft.

Table 7. Constants for Noise Barrier Attenuation Calculation

Noise Source	Dominant Sound Frequency fo(H_z)	Source Height Above Ground H(ft)
IL	125	10
HS,MS,IS	550	10
CS,IB,OB MR,IR	2500	1
RC	1250	8
CT,HT	550	8
CI	1250	3
LT	550	15

2.6 Insertion Loss Due to Buildings

Residential and Commercial Land Uses

On the basis of railyard location data, it was determined that noise attenuation factors due to buildings were necessary for three cases: (1) very low density areas, (2) residential areas with single-floor houses, and (3) residential, commercial or other areas with multi-floor buildings.

Typical insertion loss factors for the first row and additional rows of buildings have been previously determined (15,16,20,21,22). These factors were developed generally for highway traffic noise sources (line sources).

When the overall conditions, including background noise effects, are taken into consideration, the expected total insertion loss for several rows of buildings was in the range 5 dB for surburban residential areas (single-floor dwellings), and 10 dB for higher-density areas with multi-floor buildings. The resulting insertion loss values used in the model for 3 different population density ranges are listed in Table 8. Values of 4 and 8 dB are used in place of 5 and 10 dB, respectively, to compensate for the variability in attenuation with distance from the wall, and the inclusion of the insertion loss at DN, rather than after the first one or two rows of buildings.

Table 8. Noise Attenuation Due to Buildings on Receiving Properties

LOCAL AVERAGE POPULATION DENSITY (PEOPLE/SQ. MI.)	INSERTION LOSS:AR (dB)
<2000	0
2000 to 8000	4
>8000	8

Industrial Buildings

In those cases where there are other land uses between the railyard and receiving property, the attenuation due to buildings on the intervening property is accounted for. The insertion loss factors used are shown in Table 9. It was assumed that there were no buildings on undeveloped and agricultural land. The insertion loss applicable for moving sources is less than for stationary sources since any industrial buildings act as a truncated or finite barriér.

Table 9. Noise Attenuation Due to Buildings on Properties Between Railyard and Receiving Areas

	Insertion Loss (dB): AI		
Type Of Land Use	Moving Sources	Stationary Sources	Moving and Stationary Sources
Undeveloped	0	0	0
Agricultural	0	0	0
Industrial	5	10	7

2.7 Variable Input Data

The variable input data are railyard specific. In general they are determined for a sample railyard from EPIC analyses and source activity data provided by the railyard operator (rail carrier company).

The locations of noise sources, source operation patterns (lengths of travel, etc.), locations and sizes of residential and commercial areas, and distances from noise sources to receiving properties are determined from examination of USGS map and aerial photographs (EPIC analyses). However, usually not all the data required to determine the sourcs locations and activity rates, durations of operations, and daily distribution of operations are provided. Therefore other factors and assumptions have to be included in the data development.

Examples of typical variable input data for particular railyard type are shown in Table 10. The method of derivation of these parameters is discussed in more detail in sub-section 2.9, Railyard Activity Data, and section 3.0, Derivation of Input Data.

The data shown in Table 10 indicate that for this example the study area around the railyard is 50% residential and commerical land use, and there are 5 separate areas designated as residential or commercial (impacted receiving properties). In the case of the first area (R 1), the receiving property is 4000 ft in length (parallel to the railyard), 8000 ft. wide, and is impacted by 3 moving noise sources. The distance (DN) from these sources to the nearest side of R1 is 300 ft., and the distance (DB) from the railyard boundary to R1 is 100 ft. The intervening land use is industrial, and it is assumed that industrial buildings result in an insertion loss (AI) of 5dB in the noise level between the source and the receiving property (R1). Since the local average population density is in the 2000 to 8000 people/sq. mi. range, it is assumed that single family dwellings are on the property, and the noise level attenuation (insertion loss) due to the buildings (AR) is 4 dB.

Table 10. Variable Input Data for Noise Impact Model: Sample Railyard Example

RAILYARD I.D.	YARD TYPE/ TRAFFIC CATEGORY	AVERAGE POPULATION DENSITY	RESIDENTIAL COMMERCIAL LAND USE FACTOR	NUMBER OF RECEIVING PROPERTIES
Name/City/ State	Hump Class./ High	5000	0.5	5

IMPACT AREAS	LENGTH (FT.)	WIDTH (FT.)	DB (FT.)	ATT(dB) AB,AR	DN(FT.) MOVING	DN(FT.) STA.	NUMBER OF SOURCES MOVING	NUMBER OF SOURCES STATIONARY
R1	4000	8000	100	5,4	300	0	3	0

NOISE SOURCE	NED	NEN	NH1	NH2	NH3	NU1	NU2	NU3
HS	45	30	-	-	-	-	-	-
IB	10	5	-	-	-	-	-	-
OBI	7	3	-	-	-	-	-	-

IMPACT AREA	LENGTH (FT.)	WIDTH (FT.)	DB (FT.)	ATT(dB) AB,AR	DNC(FT.) MOVING	DNC(FT.) STA.	NUMBER OF SOURCES MOVING	NUMBER OF SOURCES STATIONARY
R2	2000	6000	0	0, 4	300	400	2	2

NOISE SOURCE	NED	NEN	NH1	NH2	NH3	NU1	NU2	NU3
MS	20	10	-	-	-	-	-	-
OB2	5	2	-	-	-	-	-	-
MR	1500	1000	-	-	-	-	-	-
LT	-	-	8	4	0	2	1	0

Impact Area - - - - - - -etc.

R_3

-

-

-

-

etc.

The source activity data indicate the hump switch engines (HS) move a total of 75 blocks of railcars per day (45 blocks during the day-time, and 30 blocks during the night-time), and there are 15 inbound trains (IB) per day and 10 outbound road haul trains (OB1) per day distributed during the day and night as shown.

2.8 Population Density

The population data for a sample railyard is generated by Consolidated Analyses Centers, Inc. (CACI) using their Site II System data base and computer program which incorporate 1970 block level census data. This program accesses and summarizes the 1970 census at the block and block group levels and also estimated the 1977 population for a selected study area based on such information as public utility connections and residential construction rates. The CACI system produces a Demographic Profile Report, a sample of which is shown in Figure 4.

The study area is rectangular in shape and equal to the length of the railyard complex, and extends either 2500 ft (762 m) or 5000 ft (1524 m) on each side depending on the size of the yard (i.e., 5000 ft (1524 m) for classification yards and 2500 ft (762 m) for industrial and small yards). The site specific or local average population density is obtained by dividing estimated 1977 population by the area within the rectangular coordinates of the study area (excluding the railyard area).

The site specific or local average population density is not equal to true residentail density since in the study area, the land surface area used to obtain the density value includes the commercial, industrial, agrigultural, and undeveloped land. In the model it is assumed that the people are contained in the residential and commercial areas around the railyard within the study area. The residential-commercial land use function is determined for EPIC analyses which are discussed in a later section. Therefore the impacted population density (ρr) is obtained by dividing the local average ρ by the residential land use fraction (r).

```
                         DEMOGRAPHIC PROFILE REPORT

MILL ST. YARD
AKRON, OHIO                     * * * * * * * * * * * * * * * * * * * * * * *
                                *                           LATEST    CHANGE *
            DEG MIN SEC         *                                    FROM 70 *
LATITUDE     41   7  30         * 1977 POPULATION            3691       -893 *
LONGITUDE    81  30   0         * 1977 HOUSEHOLDS            1420       -166 *
                                * 1977 PER CAP INCOME      $ 3895     $ 1064 *
 4 POINT POLYGON                *                                            *
                                *    ANNUAL COMPOUND GROWTH  -3.0%           *
WEIGHTING PCT   100%            * * * * * * * * * * * * * * * * * * * * * * *

                              1970 CENSUS DATA

POPULATION               AGE AND SEX
TOTAL        4584  100.0%                  MALE             FEMALE        TOTAL
WHITE        3328   72.6% 0-5          227  10.0%        234  10.1%       10.1%
NEGRO        1253   27.3% 6-13         320  14.1%        320  13.8%       14.0%
OTHER           3    0.1% 14-17        203   9.0%        183   7.9%        8.[illegible]
                          18-20        201   8.9%        177   7.6%
SPAN           13    0.3% 21-29        388  17.1%        320  13.8%       1[illegible]
                          30-39        162   7.1%        207   8.9%        8.0%
                          40-49        231  10.2%        196   8.5%        9.3%
FAMILY INCOME (000)       50-64        273  12.0%        371  16.0%       14.0%
$0-5          334   32.0% 65 +         262  11.6%        311  13.4%       12.5%
$5-7          148   14.2% TOTAL     2267              2319
$7-10         259   24.8% MEDIAN(AGE)      25.2                27.9       26.4
$10-15        225   21.6%
$15-25         70    6.7% HOME VALUE (000)         OCCUPATION
$25-50          4    0.4% $0-10        198  44.9%  MGR/PROF      209  13.9%
$50 +           4    0.4% $10-15       208  47.2%  SALES          56   3.7%
TOTAL        1044         $15-20        34   7.7%  CLERICAL      250  16.6%
                          $20-25         0   0.0%  CRAFT         199  13.2%
AVERAGE    $ 8082         $25-35         1   0.2%  OPERTIVS      404  26.8%
MEDIAN     $ 7463         $35-50         0   0.0%  LABORER        85   5.6%
                          $50 +          0   0.0%  FARM            1   0.1%
                           TOTAL       441         SERVICE       275  18.3%
RENT                                               PRIVATE        27   1.8%
$0-100        788   80.9% AVERAGE $10524
$100-150      162   16.6% MEDIAN  $10529
$150-200       19    2.0% % OWNER   31.2           EDUCATION  ADULTS > 25
$200-250        4    0.4%                          0-8           819  36.4%
$250 +          1    0.1%                          9-11          653  29.0%
TOTAL         974         AUTOMOBILES              12            627  27.9%
                          NONE         532  33.7%  13-15          73   3.2%
AVERAGE     $  75         ONE          760  48.2%  16 +           76   3.4%
MEDIAN      $  62         TWO          230  14.6%
% RENTER     68.8         THREE+        55   3.5%
                                                   HOUSEHOLD PARAMETERS
                                                   FAM POP      3714  81.0%
UNITS IN STRUCTURE        HOUSEHOLDS WITH:         INDIVIDS      636  13.9%
1             803   52.0% TV          1365  86.1%  GRP QTRS      234   5.1%
2             275   17.8% WASHER      1031  65.0%  TOT POP      4584
3-4           114    7.4% DRYER        454  28.6%
5-9            81    5.2% DISHWSH       56   3.5% NO OF HH:S     1586
10-49         209   13.5% AIRCOND      144   9.1% NO OF FAM:S    1098
50 +           63    4.1% FREEZER      249  15.7% AVG HH SIZE     2.7
MOBILE          0    0.0% 2 HOMES       49   3.1% AVG FAM SIZE    3.4

                                                                   CACI,INC
```

Figure 4. DEMOGRAPHIC PROFILE REPORT OF MILL STREET YARD AKRON, OHIO

2.9 Railyard Activity Data

In general, two sources of data are required to determine the activity rates and traffic parameters for the railyard noise sources. The principal activity data for individual sample railyards are obtained from the resspective railroad companies via a survey questionnaire. However, the survey questionnaire and the rail carrier response do not provide all the source activity factors required by the model. Therefore, some of the activity parameters are developed from typical or average railyard traffic data for each general type of yard provided by a DOT/FRA study.

The average activity rates in terms of low, medium and high traffic categories for hump and flat classification type yards as determined by DOT/FRA are listed in Tables 11 and 12, respectively. The average data for the industrial and small industrial type yards are listed in Tables 13 and 14. In general, when required, the range of traffic rate values for the low, medium and high traffic categories are used to judge which category a sample classification yard should be placed. These key traffic rate ranges for classification yards are shown in Table 15. It is sometimes necessary, however, to use the area of the classification portion of the railyard to judge in which category the yard belongs. The estimated ranges of areas for the three categories are listed in Table 15. The

TABLE 11

Average Activity Rates for Hump Classification Yards

Activity Parameter	Traffic Rate Category		
	Low (<1000)*	Medium (1000 to 2000)*	High (>2000)*
[No. of Classification Tracks	26	43	57]
Receiving Tracks	11	11	13
Departure Tracks	9	12	14
Standing Capacity of Classification Yard	1447	1519	2443
Standing Capicity of Receiving Yard	977	1111	1545
Standing Capacity of Departure Yard	862	969	1594
[Cars Classified Per Day	689	1468	2386]
Local Cars Dispatched Per Day	86	250	315
Industrial Cars Dispatched Per Day	74	86	220
Road-Haul Cars Dispatched Per Day	632	1050	2297
Cars Reclassified Per Day	94	195	275
Cars Weighed Per Day	74	42	149
Cars Repaired Per Day	38	43	153
Trailers & Containers Loaded or Unloaded Per Day	36	30	39
Average Time In Yard (Hours)	21	22	22
Inbound Road-Haul Trains Per Day	8	14	27
Outbound Road-Haul Trains Per Day	8	14	25
Local Trains Dispatched Per Day	2	3	5
Hump Engine Work Shifts Per Day	3	5	6
Makeup Engine Work Shifts Per Day	3	6	11
Industrial Engine Work Shifts Per Day	2	2	10
Roustabout Engine Work Shifts Per Day	2	1	4

*Range of number of rail cars classified per day

[] Data used for noise exposure model

TABLE 12

Average Facility Rates for Flat Classification Yards

Activity Parameter	Traffic Rate Category		
	Low (<500)*	Medium (500 to 1000)*	High (>1000)*
[No. of Classification Tracks	14	20	25]
Standing Capacity of Classification Yard	643	983	1185
[Cars Classified Per Day	288	711	1344]
Local Cars Dispatched Per Day	72	93	182
Industrial Cars Dispatched Per Day	47	69	121
Road-Haul Cars Dispatched Per Day	218	472	942
Cars Reclassified Per Day	60	196	349
Cars Weighed Per Day	14	21	16
Cars Repaired Per Day	13	28	31
Trailers & Containers Loaded or Unloaded Per Day	22	22	76
Average Time In Yard (Hours)	19	19	18
Inbound Road-Haul Trains Per Day	3	6	10
Outbound Road-Haul Trains Per Day	3	7	11
Local Trains Dispatched Per Day	2	3	2
Industrial Engine Work Shifts Per Day	2	3	4
Roustabout Engine Work Shifts Per Day	0	1	2
Switch Engine Work Shifts Per Day	4	7	10

*Range of number of rail cars classified per day

[] Data used for noise exposure model

Table 13

Average Activity Rates for Flat Industrial Yards

Yard Activity Descriptors	Yard Activity Level
Inbound Road-Haul Trains Per Day	1
Outbound Road-Haul Trains Per Day	1
Local Trains Dispatched Per Day	1
Cars Switched Per Day	140
Switch Engine Work-Shifts Per Day	3

Table 14

Average Activity Rates for Small Industrial Flat Yards

Yard Activity Descriptors	Yard Activity Level
Inbound Local Trains Per Day	1
Outbound Local Trains Per Day	1
Cars Switched Per Day	30
Switch Engine Work-Shifts Per Day	1

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TABLE 15

RANGE OF TRAFFIC RATE PARAMETERS FOR CLASSIFICATION YARDS*

	Hump			Flat		
	Low	Med	High	Low	Med	High
● Railcars Classified Per Day	< 1000	1000 to 2000	> 2000	< 500	500 to 1000	> 1000
● Total Switch Engine Shifts Per Day	< 12	12 to 22	> 22	< 8	8 to 13	> 13
● Total Inbound and Outbound Trains Per Day	< 24	24 to 44	> 44	< 12	12 to 20	> 12
● Area** of Classification yard (millions of sq. ft.)	< 2	2 to 4	> 4	< 1	1 to 2	> 2
● Number of trains per day						
Inbound	8	14	27	3	6	10
Outbound (road)	8	14	25	3	7	11
Outbound (local)	2	13	5	2	3	2
● Make-up switcher shifts/day	3	6	11	-	-	-
Industrial switcher shifts/day	4	3	14	2	3	4
Other switcher shifts/day	2	1	4	0	1	2

---

*FRA data

**Area = $d_{eq} \times w_{eq}$; where $d_{eq} = 2 \times Nc \times dc/Nt$; and $w_{eq} = Nt \times dt$. Nc = No. cars/day, dc = car length (65 ft.), Nt = No. of classif. tracks and dt = dist. between tracks (15 ft).

derivation of the area estimates is given at the bottom of Table 15. Thus, when the key activity parameters are not provided, a map of the railyard can be used to compute the classification yard area by multiplying its length (from the master retarder end to the inert retarder end) by its width (outer track on one side to the outer track on the opposite side). Then, by comparing the resulting area to the area ranges shown in Table 15, a judgment can be made regarding the traffic rate category for the yard.

Examples of activity survey response data for a hump and a flat classification yard are shown in Tables 16 and 17, respectively. The first part (a) of each table gives monthly and daily traffic data, while the second part (b) indicates activity rates by shift (1,2, and 3) for a typical peak activity day.

Table 16 (a) Example of Hump Classification Yard Activity Survey Response From Rail Carrier

For the following questions, please provide your *estimate* for the average month, typical peak month in recent past, and typical peak day.

	Avg.+ Month	Typical Peak Mo. in Recent Past	Typical Peak Day
a. *est.* No. of trains and transfer runs arriving/departing (exclude through trains)			
1. Trains	1175	1300	46
2. Transfer	62	70	2
b. *est.* No. of through trains	480	540	22
c. *est.* Switch-engine tricks worked by:			
1. Switch engines	507	544	18
2. Road switchers	31	31	1
3. Road power temporarily assigned to switcher service.	---	---	---
d. *est.* No. of cars handled (single count)*	69,500	76,500	3000
e. *est.* No. of cuts handled.	3565	3900	130
f. *est.* No. of mechanical reefers spotted	---	---	---
g. *est.* No. of mechanical refrigerator trailers and/or containers spotted	---	---	---

Additional or qualifying comments Pre-Trip mechanical refrigerators on the rip track 5 days a week, averging 30 to 75 cars a day, depending on the season of the year.

+Number of days yard is worked in average month 30.

*What percent of your total handling capacity is represented by the peak day figure? 75%.

Table 16 (b) Hump Yard Example

For the peak day, please provide your *estimate*+ of the following information for those items that apply to this yard.

	First Trick*		Second Trick		Third Trick	
	First 4 hrs	Second 4 hrs.	First 4 hrs.	Second 4 hrs.	First 4 hrs.	Second 4 hrs.
a. No. of trains and transfer runs arriving/departing.						
1. Trains	12	9	15	15	8	15
2. Transfer runs	0	0	0	1	1	0
b. o % time of switch engine tricks worked in yard.	100%	100%	100%	100%	100%	100%
o % time of switch engine tricks worked at industry.	---	---	---	---	---	---
o No. of switch engines parked idle in yard.	---	---	---	---	---	---
o No. of road engines parked idle in yard.	---	---	---	---	---	---
o No. of switch engines working.	6	6	6	6	6	6
o No. of road engines working	---	---	---	---	---	---
c. No. of cars handled, single count.	500	500	500	500	500	500
d. No. of cuts handled.	25	21	20	20	22	22
e. No. of mechanical refrigerator trailers and containers set out.	---	---	---	---	---	---
f. No. of mechanical reefers set out.	---	---	---	---	---	---
g. No. of cars delivered to bulk facility.	---	---	---	---	---	---
h. No. of cars delivered to TOFC/COFC facility.	---	---	---	---	---	---
i. Estimated number of road trucks arriving at this yard (not hostler trucks).	---	---	---	---	---	---
j. No. of cars hauled through inert retarders.	300	270	250	250	280	280
k. No. of engines load tested at each test cell.	0	1	0	0	0	0

COMMENTS ________________________________

* Please specify hour of the day for start of first trick (for example - 7AM, 8:15AM) 7am - 8am.

+ For many of the items above, detailed data are not readily available. We recognize that responses therefore, will be estimates based on your experience.

Table 17 (a) Example of Flat Classification Yard Activity Survey Response From Rail Carrier

For the following questions, please provide your *estimate* for the average month, typical peak month in recent past, and typical peak day.

	Avg.+ Month	Typical Peak Mo. in Recent Past	Typical Peak Day
a. *est.* No. of trains and transfer runs arriving/departing (exclude through trains)			
1. Trains	1320	1440	48
2. Transfer	390	440	15
b. *est.* No. of through trains	360	366	13
c. *est.* Switch-engine tricks worked by:			
1. Switch engines	900	930	35
2. Road switchers	0	0	0
3. Road power temporarily assigned to switcher service.	0	0	0
d. *est.* No. of cars handled (single count)*	120,000	135,000	4200
e. *est.* No. of cuts handled.	6000	6510	210
f. *est.* No. of mechanical reefers spotted			
g. *est.* No. of mechanical refrigerator trailers and/or containers spotted	4500 T 1500 C	5000 T 2000 C	250 T 125 C

Additional or qualifying comments ______________________________

+Number of days yard is worked in average month 31

*What percent of your total handling capacity is represented by the peak day figure? 100 %

Table 17 (b) Flat Classification Yard Example

For the peak day, please provide your *estimate*+ of the following information for those items that apply to this yard.

	First Trick*		Second Trick		Third Trick	
	First 4 hrs	Second 4 hrs.	First 4 hrs.	Second 4 hrs.	First 4 hrs.	Second 4 hrs.
a. No. of trains and transfer runs arriving/departing.						
1. Trains	8	4	7	8	10	7
2. Transfer runs	2	4	3	2	1	3
b. o % time of switch engine tricks worked in yard.	100%	100%	100%	100%	97%	97%
o % time of switch engine tricks worked at industry.	0	0	0	0	3%	3%
o No. of switch engines parked idle in yard.	3	2	3	2	3	3
o No. of road engines parked idle in yard.	3	0	2	4	6	3
o No. of switch engines working.	12	12	13	13	10	10
o No. of road engines working	0	0	0	0	0	0
c. No. of cars handled, single count.	750	650	700	900	700	500
d. No. of cuts handled.	50	30	45	25	35	25
e. No. of mechanical refrigerator trailers and containers set out.	0	0	0	0	0	0
f. No. of mechanical reefers set out.	0	0	0	0	0	0
g. No. of cars delivered to bulk facility.	0	0	0	0	0	0
h. No. of cars delivered to TOFC/COFC facility.	70%	10%	7%	7%	3%	3%
i. Estimated number of road trucks arriving at this yard (not hostler trucks).	0	0	0	0	0	0
j. No. of cars hauled through inert retarders.	0	0	0	0	0	0
k. No. of engines load tested at each test cell.	1	0	0	0	0	0

COMMENTS ________________________________

* Please specify hour of the day for start of first trick (for example - 7AM, 8:15AM) 7:00 a.m.

+ *For many of the items above, detailed data are not readily available. We recognize that responses therefore, will be estimates based on your experience.*

- It is assumed that the number of load tests per day is equal to the number of locomotives tested per day at "each cell" (as reported on the survey) times the number of load test cells reported.
- The number of idling locomotives is determined from the peak day distribution given in the survey return.
- It is assumed that the number of refrigerator cars "spotted" means the number operating in the yard during a 24 hour period.
- The number of inbound and outbound trains of each type (road-haul vs. local) is determined by ratioing the activity survey return data according to the yard type average values previously given by DOT (per Tables 11 and 12.
- The number of cuts moved by the make-up industrial switchers in hump yards is determined by ratioing the total number of cuts/day listed in the survey returns by the average numbers of switcher shifts per day given by DOT (see Tables 11 and 12).

For hump yards with two separate hump classification areas (one at each end of the facility), it is assumed that the survey return data are the total numbers for both hump areas, and that each hump area handled one-half the total number of cars classified, one-half the total cuts, etc.

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2.10 Numbers of Railyards

The numbers of railyards in the U.S. by functional type as previously determined for the DOT/FRA are given in Table .

Table 18. Railyard Numbers and Distribution by types and Traffic Rate Category

Yard Type	Traffic Rate Category Low	Medium	High	Total
Hump Classification	46	47	31	124
Flat Classification	571	357	185	1113
Industrial	-	-	-	1381
Small Industrial	-	-	-	1551
				4169

Based on more recent survey data, a revised estimated of the numbers of railyards in the U.S. is shown in Table .

Table 19. Estimated Numbers of Active Railyards in the U.S.

Yard Type	Traffic Rate Low	Medium	High	Total
Hump Classification	44	51	29	124
Flat Classification	476	346	130	952
Industrial	-	-	-	838
Small Industrial	-	-	-	1719
				3693

3.0 Derivation of Input Data

3.1 Introduction

The input information required for the railyard noise exposure or impact model consists generally of fixed and variable data. The fixed input data are constants associated with type of noise source and each type of yard. The variable input data are dimension and activity rate values associated with each individual sample railyard. The required fixed and variable input parameters and the respective data sources have been described in Section 2.9 (see Tables 4 through 10). This section discusses further the derivation of dimension and activity rate data and associated assumptions.

Classification rail yard complexes are typically composed of yard areas with three separate functions: receiving, classification and departure. In general, specific activities and functions are performed in each component yard and thus, the different yard noise sources are located by function in the component yards. These noise source distributions within the component yards are presented in Table 20.

Hump and flat classification yards thus have similar areas which are differentiated by the specific function performed. Except for retarders, which are not found in flat yards, the distribution of sources in flat yards assumed to be generally as shown in Table 20. However, the other flat yards do not perform all of the functions performed in the classification yards and the noise source types and operation areas are distributed differently. Discussions with rail industry personnel indicated that, in general, switch engines operate at each end of the yard, and the other sources are located inside the main yard area. The general noise source location areas for industrial and small industrial flat yards are indicated in Table 21.

The noise source and receiving property locations for specific yards are determined as discussed briefly in subsection 1.2 and in more detail below in section 3.2.

The noise generation equations (or models) developed for each type of rail yard noise source are given in section 3.1. The noise generation equations are developed in terms of L_{dn} for each type of source. The L_{dn} value for each yard source is computed using the empirical data base on railyard source noise levels, and from the yard activity survey data.

Table 20

CLASSIFICATION YARD NOISE SOURCE GROUPINGS AND DISTRIBUTION BY COMPONENT YARD TYPE*

Receiving Yard		Classification Yard		Departure Yard	
Source Location (a) Area	Hump Switchers Inbound Trains	Source Location (b) Area	Retarders (Master and Group) TOFC/COFC Idling Locomotives Load Tests Car Impacts	Source Location (d) Area	Makeup Switchers Industrial Switchers Outbound Trains
		Source Location (c) Area	TOFC/COFC Inert Retarders Refrigeration Cars Car Impacts		

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*Except for retarders, source operations and distribution are similar for classification flat yards.

Table 21

INDUSTRIAL AND SMALL INDUSTRIAL FLAT YARD NOISE SOURCE GROUPINGS

Industrial		Small Industrial	
	Noise Source		Noise Source
Area (a)	Inbound Trains Switch Engines	Area (a)	Inbound Trains Switch Engines
Area (b)	Car Impacts Outbound Trains	Area (b)	Car Impacts Outbound Trains

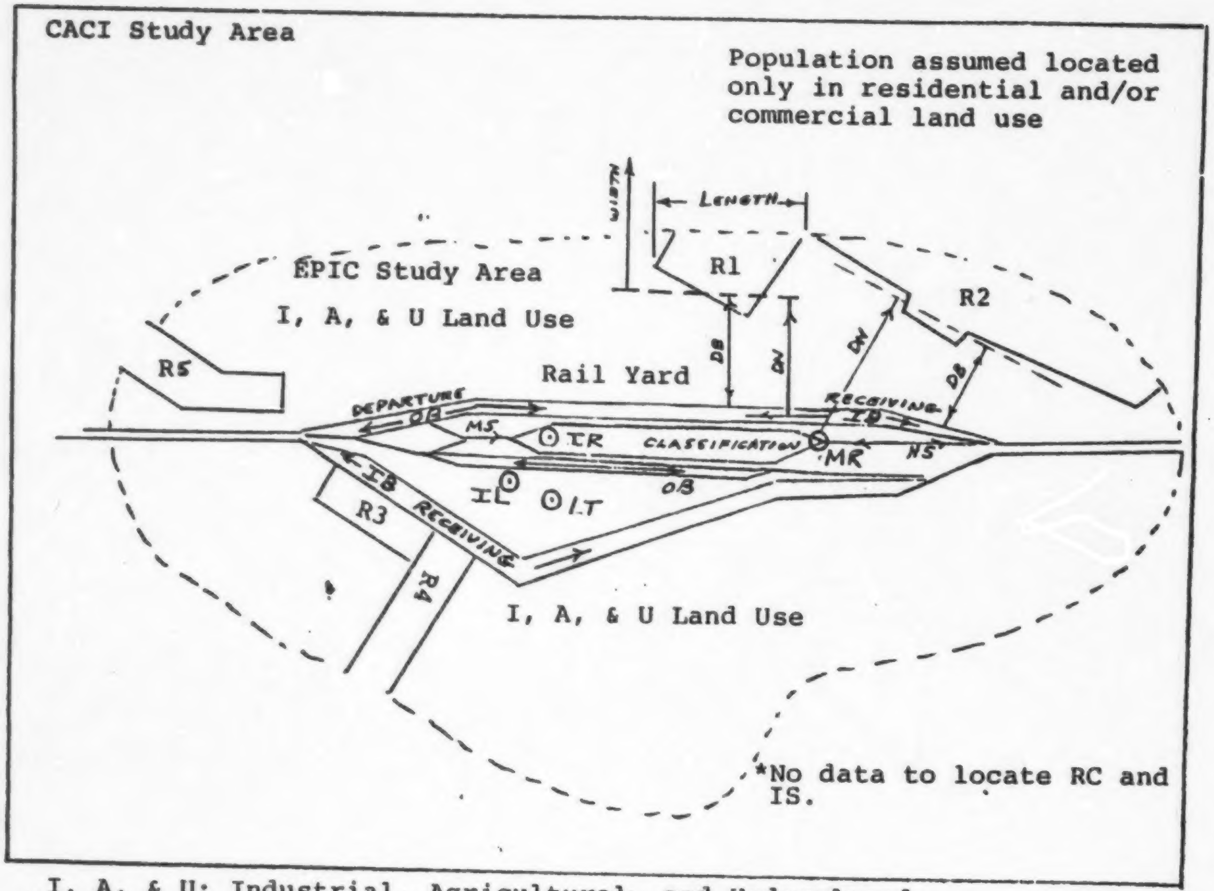
3.2 Source Location and Receiving Area Dimensions

The source locations and noise impacted area (receiving property) dimensions are determined from railyard area maps and land use analysis overlays at each sample railyard for each of the land use segments designated residential or commercial. The required dimensional data-length, width, distance from receiving property to railyard boundary (DB), and distance from source to receiving area (DN), are listed in the variable input data as shown in Table 10.

The length of the receiving property generally parallels the tracks in the railyard, and represents the travel distance for the corresponding moving sources impacting the area. Also, noise barrier walls required to meet various alternative facility noise emission standards are assumed equal in length to the impacted area. The width of each area is the distance from the boundary of the receiving property nearest the railyard to the far side of the area. The term DB is the distance from the near side of the receiving property back to the railyard boundary, and is used to determine the distance from noise barrier wall placement (at the railyard boundary) to the noise receiving area. The noise receiving area is always assumed to begin at $\geq$ 50 ft. beyond the noise wall position.

A diagram for an example hump yard configuration, with source locations and surrounding land use patterns, is shown in Figure 5. In this typically complex configuration, there is one hump area, but two receiving and two departure areas. Stationary source locations are determined from the USGS map

Figure 5. Example of Complex Railyard Configuration - High Volume Hump Yard, Flat Rock Yard, Detroit, MI


CACI Study Area
Population assumed located only in residential and/or commercial land use
WIDTH
LENGTH
R1
R2
R3
R4
R5
EPIC Study Area
I, A, & U Land Use
Rail Yard
DB
DW
DW
DB
DEPARTURE
OB
MS
IR
CLASSIFICATION
MR
RECEIVING
IB
HS
IB
IL
LT
OB
RECEIVING
I, A, & U Land Use
*No data to locate RC and IS.

I, A, & U: Industrial, Agricultural, and Undeveloped

MR: Master/Group Retarders
HS: Hump Switcher
IR: Inert Retarder
MS: Make Up Switcher

LT: Load Test Cell
IB: Inbound Trains
OB: Outbound Trains
RC: Refrigerator Cars

IL: Idling Locomotives
CI: Car Coupling Impact
IS: Industrial and other Switchers

of the railyard area, from yard configuration analyses conducted by EPIC, and from railyard drawings attached to the activity survey returned by the rail carrier. The moving source locations or operation patterns are estimated by their function relative to the yard areas. Thus, the hump switcher operates at the master retarder end of the classification area, while the make-up switcher is assumed to operate out of the inert retarder end of the classification area. In-bound and out-bound trains are assumed to operate in the receiving and departure yards, respectively. However, the location of operation of the industrial and other switchers is not defined by the available information, and arbitrary assumptions for the location are required. A practical assumption is to divide the operations between the receiving and departure areas at each end of the railyard complex. Also, in this case it is assumed that the in and out bound trains are evenly divided between the two receiving and two departure areas.

Examples of dimensional parameters for this case are indicated on the diagram in Figure 5. Even though the receiving properties (R1, to R4) are irregular in shape, it is assumed that on the average the areas are parallel to the moving sources, and that DN and DB for both moving and stationary sources are placed perpindicular to a line representing the near side of each area at an average distance from the source. The source to receiver distances, and lengths and widths of the area are sealed from the available maps and drawings.

3.3 Noise Source Activity Rates

3.3.1 Hump Yards

Inbound/Outbound Road-Haul and Local Train Operations

Based on average train lengths and power requirements, it is assumed that the local and road-haul trains entering, and the road-haul trains leaving, the yard complex are powered by three engines (NL = 3). Local out-bound trains were assumed to have one locomotive (NL = 1). Train operations are assumed to take place within the receiving and departure yard components at a speed of approximately 5 MPH. The number of pass-bys (NP), number of virtual sources (NV), number of events per source or train (NES), and event probability (EP) are all equal to a value of one. For each sample yard the arrivals and departures are assumed to be uniformly distributed over the daytime and nighttime shifts and were divided between the shifts (NED and NEN) according to the corresponding activity survey data. The number of each type of train was obtained by ratioing the total number in- and out-bound trains with the average inbound, outbound, and local trains for low, medium, or high activity category yards (per Table 11).

Hump Switch Engine Operations

Hump engine operations are assumed to operate between the receiving area and the classification area at a speed of approximately four miles per hour. It is assumed that the number of cuts per day given by the activity survey for each sample yard represents the total cuts per day worked by the hump switchers. The number of total pass-bys for hump engine cuts is computed by multiplying by two. The factor of two accounts for the number of passes required by each hump operation, one to get into position to push the cut of cars and another to perform the push. All other fixed activity parameters (NL, NV, etc.) are equal to one. The distribution of number of cuts during daytime and nighttime (NED and NEN respectively) is determined from the shift data given by the activity survey for each sample yard.

Retarders-Master, Group, Intermediate and Track

The master, group intermediate and track retarders are modeled as a grouped point source located at the goemetric center of the retarders. The Ldn resulting from cars passing through the retarders is determined from the number of cars classified per day, number of retarders passed by each car and the percentage of cars which cause retarder noise events. Examination of the available data indicated that on the average each car classified passes two retarders, and that retarder squeal occurs approximately 50 percent of the time. Therefore, the number of noise events per source (NES) is 2, but the event probability (EP) for each retarder stage is 1/2. The values of the other activity parameters (NP, NL, and NV) is one. However, since the retarder group represents a fixed point source, the value for N (the divergence loss exponent) is 2. The number of noise events (NED and NEN) is assumed equal to the day and night shift data, as given by the activity survey data.

Inert Retarders

Inert retarders are modeled as a grouped point source located at the geometric center of the retarders. It is assumed that each car leaving the classification yard passes one retarder (NES = 1) and that approximately 85 percent produce a noise event (EP = 0.85). However, the number of events (NED, NEN) for each sample yard was assumed equal to the peak day values per shift given by the activity survey for number of cars passing through inert retarders.

Car Impacts

Car impacts are modeled as two groups of stationary (virtual) sources (NV = 2), located towards each end of the classification yard component of the hump yard complex. It is assumed that the total number of car impacts is equal to one-half the number of cars "handled" (classified) per day (EP = 0.5), and that the impact noise events (NED, NEN) are distributed during day and night periods according to the survey data.

Makeup, Industrial and Other Switch Engine Operations

Makeup, industrial and other switch engine operations are modeled as moving point sources which operate in the receiving or departure component of the hump yard complex at a speed of approximately four miles per hour. It is assumed that the total number of cars leaving the classification yard component per day is equal to the number "handled" (classified) per day, and the total number of cuts is the same as for the hump switchers. The make up and industrial switcher cuts are ratioed according to the corresponding work shifts indicated in Table 11. The day and night period events (NED, NEN) is determined from the total number of cuts, and the cuts per shift data given in each activity survey return. The total number of pass-bys per switcher per day is determined by multiplying the number of corresponding cuts by 2 (NP = 2). The value of all other activity parameters (NL, NV, NES, EP) is equal to 1.

Idling Locomotives and Refrigerator Cars

Both idling locomotives and refrigeration cars are modeled as grouped stationary sources located as indicated by the survey data for each sample yard. This is considered appropriate since, in general, the distance to the receiving areas are such that the sources appear to be concentrated or superimposed. The variable activity parameter values required (NH1, NU1, etc.) were obtained for each shift from the activity survey data (peak day) for each sample yard.

Locomotive Engine Load Tests

Locomotive load tests are located according to the activity survey data for each sample railyard. In the absence of more specific data in the activity survey response it is assumed that one 6-hour test was performed per day with 4 and 2 hours of operation occuring during the daytime and nighttime periods, respectively. Otherwise, the load tests are assumed conducted during the 4 hour periods indicated per shift by the activity survey data.

3.3.2 Flat Classification Yards

Inbound/Outbound Road-Haul and Local Train Operations

As previously discussed, it is assumed that local and road-haul trains entering and road-haul trains leaving the classification yard complex are powered by three engines and local departing trains use only locomotive. Train operations are assumed to take place in the receiving and departure yard components at a speed of approximately five miles per hour. The fixed and variable activity parameters, and associated assumptions were determined or derived in the same manner as discussed for hump yards.

Switch-Engine Operations: Classification, Industrial, and Roustabout

Switch engines are assumed to operate at the receiving and departure areas in each end of the classification area at a speed of approximately four miles per hour. The rationale used in determining the operational parameters is similar to that discussed for the makeup and industrial switch engine operations in hump yards. However, it is assumed that the total number of cuts per day given in the activity survey data for each sample railyard is divided between the classification switcher and the other switchers.

Switch engine operations are modeled as two separate yard sources (NV = 2), one at each end of the yard complex. It is assumed that the switch engine operations are equally distributed between the two locations.

Car Impacts

Car impacts are modeled as four groups of stationary sources (NV = 4) located near either end of the classification area. It is assumed that the total number of car impacts is equal to one-half (EP = 0.5), the number of cars switched or classified per day.

Idling Locomotives and Refrigeration Cars

The assumptions and parameters are the same as for the hump yard case, as previously discussed.

Locomotive Engine Load Tests

As in the hump yard case, it is assumed that testing is performed for one 6-hour test and 4 and 2 hours of operation occuring during the daytime and nighttime periods, respectively, unless indicated otherwise, by the survey data. (See discussion under hump yards).

3.3.3 Industrial Yards

Inbound/Outbound Road-Haul and Local Train Operations

The activity parameters and assumptions are the same as discussed above for hump and flat classification yards. The distribution of number of road-haul and local train operations for the flat industrial yards is shown in Table . It is assumed that all train arrivals and departures are uniformly distributed over the daytime and nighttime periods, unless indicated otherwise by the peak day shift data in the activity survey returns.

Switch Engine Operations

Switch engine operations are modeled as moving sources that travel the length of the yard. The rationale used in determining the operational parameters is the same as that discussed above for the flat classification yards, except that only one virtual source is considered, since this type of flat yard is too small to warrant switching at both ends simultaneously.

Car Impacts

Car impacts are modeled as two groups of stationary sources located at each end of the yard complex (NV = 2).

It is assumed that the total number of car impacts is equal to one-half the number of cars switched per day (EP = 0.5).

3.3.4 Small Industrial Yards

Inbound/Outbound Road-Haul Train Operations

It is assumed that local trains entering or leaving the yard complex are powered by one engine. Train operations are assumed to travel to length of the yard, and arrivals and departures are distributed over the daytime and nighttime periods according to the activity survey data for each sample yard. The distribution between inbound and outbound trains was assumed equal to that shown in Table 14.

Switch Engine Operations

Switch engine operations are assumed to travel the length of the yard. The rationale used in determining the operational parameters is the same as that discussed above for the flat classification yards, except that only one virtual source is considered, since this type of flat yard is too small to warrant switching at both ends simultaneously.

Car Impacts

Car impacts are modeled as grouped sources located at each end of the yard (NV = 2). It is assumed that the total number of car impacts is equal to one-half the number of cars switched per day (EP = 0.5).

3.3.5 TOFC/COFC Operations

There are two predominant noise sources - diesel powered cranes and hostler trucks - in the TOFC areas.

It is assumed that two trailers are unloaded and loaded on each flat rail car.

Crane lift -	4 work cycles per flat car
Hostler truck -	2 work cycles per flat car

The number of flat cars worked per day and night periods (NED, NEN) are assumed equal to the peak day shift data given by the activity survey data for each sample railyard.

4.0 Use of the Model and Results

4.1 Introduction

This section provides a general description of the use (capabilities) of the model and its output data. Specific technical details necessary for using the RYNEM and understanding the program or computer code are provided in the companion documents - Volume 2, RYNEM User Manual, and Volume 3. RYNEM Programming Manual.

The basic function of the model is to compute and print out, for each individual sample railyard, noise levels at receiving properties (residential and commercial areas) and the LWP and PE values for the baseline case, and then the LWP and PE values, and benefits (LWP reductions) and costs for each case where noise barrier walls are considered at the railyard boundary to reduce the noise levels to the alternative noise limits at the receiving properties. In addition, for the baseline case, the LWP and PE values in successive 3dB intervals are computed for each and summed to obtain yard totals, and can be printed out if required.

The model can be used to compute the noise levels impact (ENI, PE) values, and noise reduction benefits and costs for an individual rail yard or a number of sample yards - either of the same type or a mix of different types. The program computes noise levels, LWP and PE values, and benefit and cost values on an area-by-area basis for each railyard, and these sums the results providing the total values for the railyard. A summation is also conducted to obtain the totals for the sample yards in each railyard category, and then the grand totals across all types of railyards.

When there are a number of sample yards of a particular type, or in each type of railyard, then the total impact, benefits and costs can be projected for the total population of a type or all types of railyards in the United States.

Thus, the capabilities of the model include selection of one or all of three levels, or degrees of detail, of output data summations:

Level I -	Grand totals for all yards
Level II -	Level I plus yard-by-yard totals for all sample yards
Level III -	Levels I and II plus output data for each source and each area at each yard.

The level I output identifies and lists data totals for each type of railyard, and also grand totals, consisting of

- Number of yards in sample
- Sample totals for PE, NI, ENI, wall costs, for 7 cases - baseline, L_{dn} receiving property limit= 75, 70, 65, 60, and 55 dB, and using maximum wall height (30 ft.)
- The number of railyards, out of the number in the sample railyards, which are already compliance at each of the alternative receiving property noise limits without the use of noise barrier (walls) at some location along the railyard boundary.
- Total population of yards, and projected values for the total population of yards of all the parameters output under sample railyards
- Total values of all these parameters (sample and projected) for all hump classification railyards, and then for all the other types (flat yards) combined. (The grand totals for all types of yards combined are obtained manually).
- Sample and projected total PE and ENI values in successive 3 dB increments (55 to 58, 58 to 61, etc., to >82 dB) for the baseline case for each type of railyard, then for all hump yards, and then for all other types (flat yards) combined.

The level II output, in addition to the level I output listings, includes for each of the sample railyards analyzed the following data:

- Total PE, ENI, ΔENI, and wall costs for the railyard at each of the alternative study cases - baseline, receiving property L_{dn} limit = 75, 70, 65, 60 and 55, and maximum wall height.
- Number of receiving areas, out of the total number for the yard, where the noise limit is achieved (by using walls at the yard boundary) at each of the alternative limits.
- Whether the yard is in compliance (the noise limit met) without using noise barriers at each of the alternative limits.
- Total ENI and PE values for the receiving areas at the yard in each successive 3 dB interval - L_{dn} = 55 to 58, 58 to 61, etc., to >82 dB.

The level III output lists all the data discussed under levels I and II and a complete set of noise level and impact data for each receiving property at each railyard for all yards analyzed. The output for each railyard consists of the following data:

For each railyard;

- Yard name, location (city and state) and type
- Local average population density, fraction of land in residential and commercial usage, effective residential population density, and background noise level
- Number of residential and commercial areas included in analysis.

For each receiving property:

- Area I.D. number, length and width
- Distance from moving sources to area, distance from fixed sources to area
- Number of moving fixed sources impacting the area
- Industrial and residential building insertion loss factors.

Baseline Case

- Each source - L_{dn}, Leq(1)max, and L_{max} at DN
- Composite L_{dn} (all sources plus background) at DN

- Total ENI and PE
- ENI and PE in each 3 dB interval (55 to 82 dB)

Alternative Noise Limits

(Composite L_{dn} limits = 75, 70, 65, 60, 55 dB)

- L_{dn}, L_{eq}(1)max, and L_{max} to DN for each source.
- Composite L_{dn}
- ENI and PE
- ΔENI (re. baseline ENI)
- Wall height and wall cost

Maximum wall height case (30 ft)

- Same data as for alternative noise limits.

4.2 Level I Output

The grand totals of the output data for all the sample railyards included in an example batch run are listed in Table 22. In the case of the medium volume hump yard sample, specific data for individual railyards (SAMPLE #YARD) were available and were analyzed to develop the required input data for the computer model. The PE, ENI, ENI (DENI), and wall cost values totaled for all 7 yards are shown for the baseline case (BL), and the other alternative cases. The baseline ENI (or LWP) for all 7 sample yards is 3560.

The #IC column indicates that 6 out of the 7 sample yards are in compliance at the L_{dn} = 75 dB limit without the use of noise barriers along the railyard boundary, whereas only 1 of the yards is in compliance at the 70 dB limit.

The total population of medium volume hump yards is estimated at 51 (PROJECTED #YD), and thus the projected total ENI for the unregulated case (BL) is 25900. Note that if noise barriers (walls) are used to reduce the noise levels at all of the yards to the L_{dn} = 65 dB limit, the projected benefit (DENI) and cost for the total yard population are, respectively, 13800 and $15.5 million. Thus a reduction in LWP of 52% is achieved.

The grand totals of the data for all the sample hump yards for all three traffic volumes are listed at the bottom of Table 22. There are 17 sample yards and 124 yards in the total population. The total projected ENI for all the hump yards is 93400. Note that only 4 (#IC) of the 17 sample yards can meet the L_{dn} = 65 dB limit without using railyard boundary walls. The cost for bringing all yards into compliance at the

65 DB limit is projected at $41.3 million, with a resulting DENI of 46400 (a benefit of 49.6% reduction in ENI).

The sample and projected total PE and ENI values in the selected 3 dB intervals for each type of yard, and the grand totals for hump yards and all flat yards are listed for this batch run in Table 23. Under hump yards - all volumes, the data listed indicate that the projected total ENI in the L_{dn} = 73 to 76 dB range is 121 for all hump yards in the U.S. For comparison in the 67 to 70 dB interval the projected total ENI is 5000.

4.3 Level II Output

In addition to the grand totals of the output data listed in Tables 22 and 23, the Level II output selection results in listings of the data totals by sample yard for each individual railyard included in a batch run. An example of the Totals for Yard for one sample railyard is shown in Table 24. This listing of totals is obtained from the example hump yard area-by-area data (Level III output) listed in Table 25, and discussed in section 4.4.

The data in Table 24 indicate that the total baseline ENI resulting from the noise sources at this particular railyard is 520, and that the yard is in compliance (IC = 1) without the use of walls at the boundary only if the noise limit is 75 dB or greater. (IC = 0, as at the other alternative limit cases, means the yard is not in compliance at that limit). Also indicated under the NA column are the number of receiving areas at the yard where the noise limit is met for each of the alternative limits after a wall is considered at the railyard boundary. The output data in this case indicate that use of walls at the yard boundary can reduce the noise levels at all 5 of the impacted areas to each of the alternative limits down to L_{dn} = 60 dB.

Table 22(a). Level I Output Listing - Baseline and Alternative Limits

```
GRAND TOTAL FOR ALL YARDS

                          SAMPLE                                                  PROJECTED

        # YD    PE        ENI       DENI      COST      # YD   PE        ENI       DENI      COST      # IC

LOW VOL HUMP

   BL     6  2.05E+04  3.16E+03  0.0       0.0         44  1.50E+05  2.32E+04  0.0       0.0          6
   75     6  2.05E+04  3.16E+03  0.0       0.0         44  1.50E+05  2.32E+04  0.0       0.0          3
   70     6  2.00E+04  2.84E+03  3.25E+02  4.26E+05    44  1.47E+05  2.08E+04  2.39E+03  3.12E+06     3
   65     6  1.73E+04  1.94E+03  1.22E+03  1.50E+06    44  1.27E+05  1.42E+04  8.97E+03  1.10E+07     0
   60     6  9.75E+03  6.32E+02  2.53E+03  3.88E+06    44  7.15E+04  4.63E+03  1.86E+04  2.84E+07     0
   55     6  0.0       0.0       3.16E+03  7.16E+06    44  0.0       0.0       2.32E+04  5.25E+07
   MW     6  4.31E+03  2.25E+02  2.94E+03  7.16E+06    44  3.16E+04  1.65E+03  2.16E+04  5.25E+07

MEDIUM VOL HUMP

   BL     7  1.98E+04  3.56E+03  0.0       0.0         51  1.44E+05  2.59E+04  0.0       0.0          6
   75     7  1.96E+04  3.49E+03  7.03E+01  9.60E+04    51  1.43E+05  2.54E+04  5.12E+02  6.99E+05     1
   70     7  1.65E+04  2.49E+03  1.07E+03  7.73E+05    51  1.20E+05  1.81E+04  7.80E+03  5.63E+06     0
   65     7  1.35E+04  1.66E+03  1.90E+03  2.13E+06    51  9.86E+04  1.21E+04  1.38E+04  1.55E+07     0
   60     7  6.94E+03  4.39E+02  3.12E+03  5.65E+06    51  5.05E+04  3.20E+03  2.27E+04  4.12E+07     0
   55     7  0.0       0.0       3.56E+03  9.14E+06    51  0.0       0.0       2.59E+04  6.66E+07
   MW     7  5.60E+03  3.41E+02  3.22E+03  9.14E+06    51  4.09E+04  2.48E+03  2.34E+04  6.66E+07

HIGH VOL HUMP

   BL     4  3.70E+04  6.09E+03  0.0       0.0         29  2.69E+05  4.41E+04  0.0       0.0          4
   75     4  3.70E+04  6.09E+03  0.0       0.0         29  2.68E+05  4.41E+04  0.0       0.0          1
   70     4  3.01E+04  4.22E+03  1.87E+03  8.80E+05    29  2.13E+05  3.06E+04  1.35E+04  6.38E+06     1
   65     4  2.43E+04  2.84E+03  3.25E+03  2.03E+06    29  1.76E+05  2.06E+04  2.35E+04  1.48E+07     0
   60     4  1.33E+04  8.94E+02  5.19E+03  5.55E+06    29  9.66E+04  6.48E+03  3.77E+04  4.03E+07     0
   55     4  0.0       0.0       6.09E+03  1.06E+07    29  0.0       0.0       4.41E+04  7.70E+07
   MW     4  6.23E+03  3.36E+02  5.75E+03  1.06E+07    29  4.51E+04  2.43E+03  4.17E+04  7.70E+07

LOW VOL FLAT

   BL    20  1.97E+04  2.14E+03  0.0       0.0        476  4.68E+05  5.09E+04  0.0       0.0         18
   75    20  1.96E+04  2.10E+03  4.25E+01  1.23E+05   476  4.67E+05  4.99E+04  1.01E+03  2.94E+06    16
   70    20  1.87E+04  1.92E+03  2.16E+02  2.96E+05   476  4.45E+05  4.57E+04  5.15E+03  7.04E+06     6
   65    20  1.43E+04  1.11E+03  1.03E+03  1.75E+06   476  3.41E+05  2.64E+04  2.44E+04  4.17E+07     4
   60    20  8.18E+03  3.93E+02  1.74E+03  4.96E+06   476  1.95E+05  9.36E+03  4.15E+04  1.18E+08     1
   55    20  0.0       0.0       2.14E+03  1.34E+07   476  0.0       0.0       5.09E+04  3.19E+08
   MW    20  1.24E+03  4.05E+01  2.10E+03  1.34E+07   476  2.95E+04  9.64E+02  4.99E+04  3.19E+08

MEDIUM VOL FLAT

   BL    17  2.58E+04  4.03E+03  0.0       0.0        346  5.25E+05  8.21E+04  0.0       0.0         15
   75    17  2.50E+04  3.85E+03  1.79E+02  8.38E+04   346  5.08E+05  7.84E+04  3.64E+03  1.70E+06    10
   70    17  2.33E+04  3.36E+03  6.72E+02  5.34E+05   346  4.74E+05  6.84E+04  1.37E+04  1.09E+07     5
   65    17  1.88E+04  2.03E+03  2.00E+03  2.11E+06   346  3.82E+05  4.14E+04  4.07E+04  4.29E+07     1
   60    17  9.78E+03  5.29E+02  3.50E+03  5.83E+06   346  1.99E+05  1.08E+04  7.13E+04  1.19E+08     1
   55    17  0.0       0.0       4.03E+03  1.39E+07   346  0.0       0.0       8.21E+04  2.82E+08
   MW    17  2.99E+03  1.38E+02  3.89E+03  1.39E+07   346  6.09E+04  2.82E+03  7.92E+04  2.82E+08
```

Table 22(b). Level I Output Listing - Baseline and Alternative Limits

```
HIGH VOL FLAT

     BL   11  4.61E+04  5.79E+03  0.0       0.0        130  5.45E+05  6.85E+04  0.0       0.0
     75   11  4.52E+04  5.44E+03  3.56E+02  1.82E+05   130  5.34E+05  6.43E+04  4.71E+03  2.15E+06     8
     70   11  4.14E+04  4.30E+03  1.50E+03  1.16E+06   130  4.93E+05  5.08E+04  1.77E+04  1.35E+07     4


     65   11  3.64E+04  3.16E+03  2.63E+03  2.64E+06   130  4.30E+05  3.74E+04  3.11E+04  3.12E+07     4
     60   11  2.17E+04  1.15E+03  4.65E+03  6.08E+06   130  2.57E+05  1.35E+04  5.49E+04  7.18E+07     1
     55   11  0.0       0.0       5.79E+03  1.35E+07   130  0.0       0.0       6.85E+04  1.60E+08     0
     MW   11  5.45E+03  2.94E+02  5.50E+03  1.35E+07   130  6.45E+04  3.47E+03  6.50E+04  1.60E+08

INDUSTRIAL

     BL   60  3.87E+04  3.45E+03  0.0       0.0        838  5.40E+05  4.82E+04  0.0       0.0
     75   60  3.86E+04  3.42E+03  3.33E+01  3.24E+05   838  5.39E+05  4.78E+04  4.65E+02  4.52E+06    55
     70   60  3.51E+04  2.75E+03  7.02E+02  1.29E+06   838  4.90E+05  3.84E+04  9.80E+03  1.61E+07    45
     65   60  2.60E+04  1.51E+03  1.95E+03  4.67E+06   838  3.64E+05  2.10E+04  2.72E+04  6.42E+07    35
     60   60  1.80E+04  6.79E+02  2.77E+03  1.03E+07   838  2.51E+05  9.49E+03  3.87E+04  1.44E+08    27
     55   60  0.0       0.0       3.45E+03  2.77E+07   838  0.0       0.0       4.82E+04  3.87E+08    10
     MW   60  1.21E+03  4.48E+01  3.41E+03  2.77E+07   838  1.69E+04  6.25E+02  4.76E+04  3.87E+08

SMALL INDUSTRIAL

     BL   58  1.87E+04  1.57E+03  0.0       0.0       1779  5.75E+05  4.82E+04  0.0       0.0
     75   58  1.83E+04  1.48E+03  9.55E+01  6.53E+05  1779  5.62E+05  4.53E+04  2.93E+03  2.00E+07    51
     70   58  1.70E+04  1.24E+03  3.34E+02  2.05E+06  1779  5.20E+05  3.80E+04  1.02E+04  6.30E+07    41
     65   58  1.13E+04  6.46E+02  9.27E+02  5.09E+06  1779  3.48E+05  1.98E+04  2.84E+04  1.56E+08    31
     60   58  5.37E+03  1.96E+02  1.38E+03  1.09E+07  1779  1.65E+05  5.03E+03  4.22E+04  3.33E+08    27
     55   58  0.0       0.0       1.57E+03  2.03E+07  1779  0.0       0.0       4.82E+04  6.21E+08    11
     MW   58  2.99E+02  1.01E+01  1.56E+03  2.03E+07  1779  9.18E+03  3.11E+02  4.79E+04  6.21E+08

HUMP YARDS--ALL VOLUMES

     BL   17  7.72E+04  1.28E+04  0.0       0.0        124  5.63E+05  9.34E+04  0.0       0.0
     75   17  7.71E+04  1.27E+04  7.03E+01  9.60E+04   124  5.62E+05  9.29E+04  5.13E+02  7.00E+05    16
     70   17  6.66E+04  9.55E+03  3.26E+03  2.08E+06   124  4.85E+05  6.97E+04  2.38E+04  1.52E+07     5
     65   17  5.51E+04  6.44E+03  6.37E+03  5.67E+06   124  4.02E+05  4.70E+04  4.64E+04  4.13E+07     4
     60   17  3.00E+04  1.96E+03  1.08E+04  1.51E+07   124  2.19E+05  1.43E+04  7.91E+04  1.10E+08     0
     55   17  0.0       0.0       1.28E+04  2.69E+07   124  0.0       0.0       9.34E+04  1.96E+08     0
     MW   17  1.61E+04  9.01E+02  1.19E+04  2.69E+07   124  1.19E+05  6.57E+03  8.69E+04  1.96E+08

FLAT YARDS--ALL VOLUMES

     BL   48  9.16E+04  1.20E+04  0.0       0.0        952  1.82E+06  2.37E+05  0.0       0.0
     75   48  8.97E+04  1.14E+04  5.77E+02  3.89E+05   952  1.79E+06  2.26E+05  1.15E+04  7.71E+06    41
     70   48  8.34E+04  9.58E+03  2.38E+03  1.99E+06   952  1.65E+06  1.90E+05  4.73E+04  3.95E+07    30
     65   48  6.95E+04  6.30E+03  5.66E+03  6.50E+06   952  1.38E+06  1.25E+05  1.12E+05  1.29E+08    15
     60   48  3.97E+04  2.07E+03  9.89E+03  1.69E+07   952  7.87E+05  4.10E+04  1.96E+05  3.35E+08     6
     55   48  0.0       0.0       1.20E+04  4.08E+07   952  0.0       0.0       2.37E+05  8.09E+08     2
     MW   48  9.69E+03  4.73E+02  1.15E+04  4.08E+07   952  1.92E+05  9.38E+03  2.28E+05  8.09E+08
```

Table 23(a). Level I OUtput - Baselino Case, 3dB Intervals

```
DB BANDS FOR BASELINE

         55-58     58-61     61-64     64-67     67-70     70-73     73-76     76-79     79-82     >82


LOW VOL HUMP

SAMPLE
PE       1.34E+04  4.97E+03  1.55E+03  6.20E+02  1.66E+02  1.45E+01  0.0       0.0       0.0       0.0
ENI      9.62E+02  1.17E+03  5.79E+02  3.21E+02  1.21E+02  1.11E+01  0.0       0.0       0.0       0.0
PROJECTED
PE       9.85E+04  3.64E+04  1.14E+04  4.55E+03  1.37E+03  1.06E+02  0.0       0.0       0.0       0.0
ENI      7.06E+03  8.61E+03  4.22E+03  2.35E+03  8.90E+02  6.12E+01  0.0       0.0       0.0       0.0

MEDIUM VOL HUMP




SAMPLE
PE       1.20E+04  4.56E+03  2.29E+03  9.56E+02  4.52E+02  1.21E+02  9.72E+00  0.0       0.0       0.0
ENI      7.60E+02  1.04E+03  8.49E+02  5.00E+02  3.06E+02  9.70E+01  9.26E+00  0.0       0.0       0.0
PROJECTED
PE       8.77E+04  3.32E+04  1.67E+04  6.97E+03  3.25E+03  8.81E+02  7.08E+01  0.0       0.0       0.0
ENI      5.54E+03  7.61E+03  6.18E+03  3.64E+03  2.18E+03  7.07E+02  6.75E+01  0.0       0.0       0.0

HIGH VOL HUMP

SAMPLE
PE       2.32E+04  7.75E+03  4.21E+03  1.41E+03  3.97E+02  1.75E+02  8.00E+00  0.0       0.0       0.0
ENI      1.50E+03  1.64E+03  1.60E+03  7.37E+02  2.64E+02  1.43E+02  7.31E+00  0.0       0.0       0.0
PROJECTED
PE       1.88E+05  5.62E+04  3.05E+04  1.02E+04  2.88E+03  1.27E+03  5.80E+01  0.0       0.0       0.0
ENI      1.09E+04  1.33E+04  1.16E+04  5.34E+03  1.91E+03  1.04E+03  5.30E+01  0.0       0.0       0.0

LOW VOL FLAT

SAMPLE
PE       1.52E+04  3.28E+03  9.73E+02  1.82E+02  3.51E+01  4.25E+00  9.66E-01  2.56E-01  0.0       0.0
ENI      9.23E+02  7.24E+02  3.64E+02  9.78E+01  2.46E+01  3.41E+00  9.26E-01  2.83E-01  0.0       0.0
PROJECTED
PE       3.62E+05  7.80E+04  2.32E+04  4.33E+03  8.35E+02  1.01E+02  2.30E+01  6.65E+00  0.0       0.0
ENI      2.20E+04  1.72E+04  8.65E+03  2.33E+03  5.66E+02  6.12E+01  2.21E+01  6.73E+00  0.0       0.0

MEDIUM VOL FLAT

SAMPLE
PE       1.71E+04  5.91E+03  1.99E+03  7.50E+02  1.62E+02  2.59E+01  3.47E+00  0.0       0.0       0.0
ENI      1.26E+03  1.46E+03  7.66E+02  3.90E+02  1.17E+02  2.11E+01  3.25E+00  0.0       0.0       0.0
PROJECTED
PE       3.48E+05  1.20E+05  4.05E+04  1.53E+04  3.76E+03  5.28E+02  7.06E+01  0.0       0.0       0.0
ENI      2.56E+04  3.00E+04  1.56E+04  7.94E+03  2.34E+03  4.29E+02  6.61E+01  0.0       0.0       0.0
```

Table 23(b). Level I Output - Baseline Case, 3dB Intervals

```
HIGH VOL FLAT

SAMPLE
PE       3.32E+04  9.51E+03  2.51E+03  8.60E+02  2.16E+02  5.74E+01  4.20E+00  2.96E-02  0.0       0.0
ENI      2.01E+03  2.19E+03  9.31E+02  4.59E+02  1.52E+02  4.99E+01  4.00E+00  4.13E-02  0.0       0.0
PROJECTED
PE       3.93E+05  1.12E+05  2.96E+04  1.02E+04  2.58E+03  6.78E+02  4.97E+01  4.61E-01  0.0       0.0
ENI      2.38E+04  2.56E+04  1.10E+04  5.42E+03  1.86E+03  5.90E+02  4.73E+01  4.86E-01  0.0       0.0

INDUSTRIAL

SAMPLE
PE       3.31E+04  4.43E+03  1.14E+03  2.22E+02  2.33E+01  4.58E+00  3.56E-01  1.82E-02  0.0       0.0
ENI      1.77E+03  1.08E+03  4.59E+02  1.24E+02  1.54E+01  3.66E+00  3.42E-01  1.95E-02  0.0       0.0
PROJECTED
PE       4.62E+05  6.18E+04  1.59E+04  3.10E+03  3.25E+02  6.40E+01  4.97E+00  2.54E-01  0.0       0.0
ENI      2.48E+04  1.50E+04  6.41E+03  1.74E+03  2.15E+02  5.11E+01  4.77E+00  2.72E-01  0.0       0.0

SMALL INDUSTRIAL

SAMPLE
PE       1.65E+04  1.99E+03  2.74E+02  6.05E+01  1.49E+01  3.77E+00  1.06E+00  2.71E-01  1.10E-03  0.0
ENI      9.25E+02  4.84E+02  1.17E+02  3.17E+01  9.85E+00  3.05E+00  1.02E+00  2.94E-01  1.33E-03  0.0
PROJECTED
PE       5.07E+05  6.09E+04  8.39E+03  1.86E+03  4.57E+02  1.16E+02  3.26E+01  8.36E+00  3.37E-02  0.0
ENI      2.84E+04  1.49E+04  3.60E+03  9.72E+02  3.02E+02  9.36E+01  3.14E+01  9.16E+00  4.07E-02  0.0



HUMP YARDS--ALL VOLUMES

SAMPLE
PE       4.67E+04  1.73E+04  8.05E+03  2.99E+03  1.04E+03  3.10E+02  1.77E+01  0.0       0.0       0.0
ENI      3.22E+03  4.06E+03  3.02E+03  1.56E+03  6.85E+02  2.51E+02  1.66E+01  0.0       0.0       0.0
PROJECTED
PE       3.55E+05  1.26E+05  5.87E+04  2.18E+04  7.55E+03  2.26E+03  1.29E+02  0.0       0.0       0.0
ENI      2.35E+04  2.96E+04  2.20E+04  1.14E+04  5.06E+03  1.63E+03  1.21E+02  0.0       0.0       0.0

FLAT YARDS--ALL VOLUMES

SAMPLE
PE       6.55E+04  1.87E+04  5.47E+03  1.79E+03  4.35E+02  8.75E+01  8.64E+00  2.95E-01  0.0       0.0
ENI      4.19E+03  4.39E+03  2.06E+03  9.47E+02  2.94E+02  7.44E+01  8.16E+00  3.24E-01  0.0       0.0
PROJECTED
PE       1.30E+06  3.71E+05  1.08E+05  3.55E+04  8.62E+03  1.74E+03  1.71E+02  5.85E+00  0.0       0.0
ENI      8.32E+04  8.70E+04  4.09E+04  1.88E+04  5.83E+03  1.48E+03  1.62E+02  6.43E+00  0.0       0.0
```

Table 24. Yard Totals - Included in Level II Output

```
TOTALS FOR YARD

   DB BANDS FOR BASELINE

         55-58     58-61     61-64     64-67     67-70     70-73     73-76     76-79     79-82     >82

PE      4.94E+03  9.64E+02  5.38E+01  0.0       0.0       0.0       0.0       0.0       0.0       0.0
ENI     2.96E+02  2.06E+02  1.75E+01  0.0       0.0       0.0       0.0       0.0       0.0       0.0

LEVEL     PE        ENI       DENI      COST      NA        IC

  BL  5.96E+03  5.20E+02  0.0       0.0         5
  75  5.96E+03  5.20E+02  0.0       0.0         5         1
  70  5.96E+03  5.11E+02  9.49E+00  5.40E+04    5         0
  65  4.99E+03  3.76E+02  1.44E+02  2.46E+05    5         0
  60  1.76E+03  7.11E+01  4.49E+02  6.92E+05    5         0
  55  0.0       0.0       5.20E+02  1.15E+06    0         0
  MW  6.05E+02  1.20E+01  5.08E+02  1.15E+06    5         .
```

The costs of walls for meeting the 60 dB limit, for example, totals $692,000. However, the benefits are a reduction in PE of 4200 (or 70%), and an 86% reduction in ENI.

4.4 Level III Output

Level I and II output plus area-by-area data for each sample yard are listed when Level III output is selected. An example of some of the area-by-area data for one sample yard is shown in Table 25. This sample railyard is the Airline yard in Milwaukee, Wisconsin, and is a type 1, or low traffic volume hump classification yard.

The local average population density is 10,152 people per square mile, and 43% of the land around the yard is in residential and commercial use. The residential area density is estimated as 23,609 people/sq. mi, and the background L_{dn} (BKGD) is 62 dB. The #AREAS column indicates there are 5 residential or commercial areas exposed to railyard noise.

Area R1, for example, is 1500 ft. in length and extends for at least 8000 ft. (width) away from the railyard. The distance (DNM) from the moving sources affecting R1 to the nearest side of R1 is 250 ft., and the distance (DB), from R1 back to the railyard boundary is 100 ft. The analysis of the railyard data indicated there is no attenuation of the noise due to industrial buildings (DI = 0) in the 100 ft. wide strip between R1 and the yard boundary. The attenuation (or insertion loss) due to residential buildings on R1 is estimated at 8 dB (DR = 8) as a result of the relatively high local average population density (10152).

Table 25(a) Individual Railyard Data Included in Level III Output

```
AIRLINE, MILWAUKEE, WI                   LOW VOL HUMP

    POP DEN  USAGE      EFF POP  BKGD    # AREAS

    10152.0   0.43      23609.3  62.1       5

   AREA  LENGTH  WIDTH   DB    DI  DR  DNM   DNF    NPS  NFS

   R1     1530.  8000.   100.  0.  8.  250.   0.     3    0

   DB BANDS FOR BASELINE

          55-58     58-61     61-64     64-67     67-70     70-73     73-76     76-79     79-82     >82

PE     1.44E+03  2.67E+02  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
ENI    7.88E+01  5.27E+01  0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0

  BL

      SOURCE  LDN   LEQ   LMAX

        HS    64.0  59.4  85.9
        IB    60.7  55.4  93.5
        DB1   60.7  55.4  93.5

      LEVEL    PE        ENI       DENI      COST       WALL

       67.1  1.71E+03  1.32E+02  0.0       0.0           0

  65

      SOURCE  LDN   LEQ   LMAX

        HS    59.0  54.4  80.9
        IR    55.7  50.4  88.5
        DR1   55.7  50.4  88.5

      LEVEL    PE        ENI       DENI      COST       WALL

       62.5  1.45E+03  9.93E+01  3.23E+01  5.55E+04     7

  60

      SOURCE  LDN   LEQ   LMAX

        HS    55.7  51.1  77.6
        IR    52.5  47.1  85.2
        DR1   52.5  47.1  85.2

      LEVEL    PE        ENI       DENI      COST       WALL

       59.9  7.59E+02  3.32E+01  9.84E+01  1.40E+05    16

  NM

      SOURCE  LDN   LEQ   LMAX

        HS    51.8  47.2  73.7
        IR    48.6  43.2  81.3
        DR1   48.6  43.2  81.3
```

Table 25(b). Individual Railyard Data Included in Level III Output

```
    LEVEL    PE         ENI      DENI      COST      WALL

     57.4  2.15E+02  3.62E+00  1.28E+02  2.66E+05   30

   AREA  LENGTH  WIDTH   DB    DI  DR  DNM   DNF    NMS  NFS

   CI/R   1000.  8000.     0.  0.  8.  100.  250.    2    1

   DP BANDS FOR BASELINE

          55-58     58-61     61-64     64-67     67-70     70-73     73-76     76-79     79-82     >82

PE     6.51E+02  1.25E+02  1.55E-02  0.0       0.0       0.0       0.0       0.0       0.0       0.0
ENI    4.52E+01  2.84E+01  4.64E-03  0.0       0.0       0.0       0.0       0.0       0.0       0.0

  BL

    SOURCE  LDN   LEQ   LMAX

      IB    65.0  59.6  97.8
      OB1   65.0  59.6  97.8
      MR    65.8  57.9  83.0

    LEVEL    PE         ENI      DENI      COST      WALL

     70.2  7.76E+02  7.36E+01  0.0       0.0        0

  70

    SOURCE  LDN   LEQ   LMAX

      IB    65.0  59.6  97.8
      OB1   65.0  59.6  97.8
      MR    60.6  52.7  77.8

    LEVEL    PE         ENI      DENI      COST      WALL

     68.9  7.76E+02  6.89E+01  4.73E+00  2.70E+04   5

  65

    SOURCE  LDN   LEQ   LMAX

      IB    60.0  54.6  92.8
      OB1   60.0  54.6  92.8
      MR    58.5  50.6  75.7

    LEVEL    PE         ENI      DENI      COST      WALL

     64.7  6.46E+02  4.92E+01  2.45E+01  3.70E+04   7

  60

    SOURCE  LDN   LEQ   LMAX

      IB    54.7  49.3  87.4
      OB1   54.7  49.3  87.4
      MR    51.9  44.3  69.0

    LEVEL    PE         ENI      DENI      COST      WALL
```

There are 3 moving sources (NMS =3) generating noise received at R1 - hump switchers (HS), inbound trains (IB), and outbound road-haul trains (OB1). There are no fixed sources at this location (NFS = 0, and thus DNF = 0). For the baseline (BL) case at R1 the noise exposures due to HS, IB, and OB1 are LDN = 64, 60.7, and 60.7, respectively. The values for maximum Leq(1) (LEQ) and maximum noise level (LMAX) at R1 are also listed for each of the 3 sources. The total or composite noise level at R1 (LEVEL), which includes a background level of L_{dn} = 54 dB (although BKGD = 62.1, it is assumed as explained previously that BKGD is reduced to 54 dB), is 67.1 dB. The baseline (no walls at railyard boundary) population exposed (PE) and level weighted population (LWP, or ENI) are 1710 and 132, respectively.

Also listed for the baseline case are the PE and ENI values in the successive 3 dB intervals (DB BANDS FOR BASELINE). Note that for R1 the composite level (LEVEL) at DN is 67.1 dB. However, the noise level is reduced by 8 dB (DR = 8) to 59.1 dB as it begins to propagate over the area, and thus the largest 3 dB interval of Ldn in which there are PE and ENI values is 58 to 61 dB.

The source noise levels (LDN, LEQ, and LMAX), composite level (LEVEL), and PE and ENI values are also listed for each alternative noise limit (65, 60, and 55 in the case of R1). These values result from considering different height walls at the yard boundary to reduce the railyard noise to the alternative limits. The impact reduction (DENI), wall costs (COST), and wall height in ft. (WALL) are also listed. For the L_{dn} = 65 dB limit, a wall height of 7 ft. is required. The wall cost is $55,500 and results in DENI of 32.2 which is a 25% reduction in noise impact. These data are listed for each noise limit, and for the case (MW) where a maximum wall height of 30 ft. is used.

The entire listing of the above type of data is then repeated for each of the remaining 4 areas (Cl/R, R2, etc.) The total of the data for all 5 areas is then listed as discussed in the previous section, 4.3 Level II output.

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